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Pictures of the Future

The Magazine for Research and Innovation | Spring 2014

Solutions for Tomorrow's World

Intelligent Energy Use

The benefits of efficiency for industry and environment

Affordable Infrastructures

Smart technologies and flexible financing

Digital Transformation

A virtual counterpart for every real-world object

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Our Digital Future

Apart from political and social upheavals, what do futurologists believe will be the most important trends in the period until 2050? They predict that population will increase by a third, and the number of people older than 65 will be three times as large as it is today. In other words, today's 500 million seniors will be joined by an additional billion. At least seven out of ten people will live in cities, and the urban centers in Asia, Africa, and Latin America will grow by a total of three billion inhabitants. Moreover, prosperity will grow in many countries, and billions of people will form a new middle class. One consequence of all this is clear. Demand for the diverse products of civilization will grow by leaps and bounds. If demand for resources and energy continues to develop at the present rate, it will double by 2050. Electricity demand, for instance, is currently growing three times as fast as the world's population.

The earth's raw materials are just as limited as its ability to absorb waste. According to futurologists, if the human race continues its current behavior, by 2050 we'll need three earths rather than the one we already have. What can we do in order not to leave our children a plundered planet full of unresolved conflicts over land, resources, and a clean environment?

One crucial success factor will be the intelligent use of raw materials and energy, ranging from the expansion of renewable sources to highly efficient combined cycle power plants, and more efficient resource use in buildings, transportation systems, and industrial plants (see pp. 10–43).

Equally important is the worldwide expansion of education and healthcare systems. A broad range of activities will help us move toward a better future — for example, the promotion of creative thinking in schools, the production of one-dollar glasses (pp. 46, 70), the early detection of malaria by means of routine tests (p. 44), and the development of new solutions for helping elderly people navigate in unfamiliar surroundings (p. 87). We will also have to make health care and transportation systems, as well as urban infrastructures, affordable for as many people as possible, for example in China, Vietnam, and the countries of Africa (pp. 48–69).

One trend may be more important than all the others, because it's changing the rules of the game in every sector: the digital transformation (pp. 74–113). A look at trends in IT indicates that during the next 20 to 25 years the computing power, storage capacity, and data transmission rate of microchips will face a thousand-fold increase. We can therefore expect that the performance of today's €500 notebook will be squeezed into a microchip worth €0.50. Software developers will be challenged to develop associated high-performance programs.

By 2020 the amount of data stored worldwide will explode to six terabytes for each individual on earth. Almost 40 percent of this data will probably be available via cloud services. Many experts believe that the digital transformation will generate a new economic boom, while simultaneously making some traditional professions superfluous (p. 90). However, current studies (p. 88) show that countries with a high degree of digitization are more competitive and have lower rates of unemployment.

Similar predictions are being made about companies. At Siemens, digital transformation will be crucial for the success of virtually all projects at its business units, including neural networks and smart grids in energy technology (pp. 18, 26), the comprehensive networking and resource-saving automation of digital factories (pp. 92, 94), remote maintenance of a wide range of systems (p. 84), cloud services and avatars (p. 79, 82), and the digital fusion of diverse medical processes and data (p. 104).

This trend is also having an impact on magazines. After 13 years, this Spring 2014 issue of *Pictures of the Future* will be the last one published in its traditional form. Starting with the Fall 2014 issue, we will transform *Pictures of the Future* into a high-quality online magazine that will not only offer new articles, pictures, videos, and animated graphics every week, but will also integrate readers' wishes and suggestions much more closely than a printed format can. We therefore hope that you, our readers, will remain loyal to us and join us as we move toward the digital future. We're looking forward to that!

The *Pictures of the Future* editorial team

P.S.: You won't have to miss *Pictures of the Future*. It will continue to be published on line and, for a limited period, also as a print magazine that will be available to subscribers as a "Best of" selection of the best, most important, and most popular online articles we offer. For more information, see page 115.

Cover: A Siemens Wind Service technician uses an iPad to perform maintenance at the Harvest Wind project in the U.S. state of Washington. Thanks to digital technologies, technicians are now able to service 12 windmills per month, rather than the previous 10. For more, turn to page 79.

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Smart electric meters and hot water tanks are expected to help diminish Canada's appetite for electricity.

Canadian Smart Grid Could Obviate Oil Plants

Canada's New Brunswick Power wants to avoid expensive load peaks. The company provides electricity to around 400,000 private, commercial, and industrial customers on a regional basis. A new ten-year partnership with Siemens is expected to help reduce customers' power demand by means of a smart grid that will distribute power from hydroelectric, nuclear, coal and heavy oil power plants. But Brunswick Power, which uses heavy oil plants to cover energy needs during the coldest winter months, is betting that the smart grid will make the plants superfluous by cutting consumer demand.

Siemens has developed a ten-year plan that includes the technical foundations of a smart grid and the development and installation of smart electric meters. The plan calls for New Brunswick Power to replace the boilers in around 80 percent of its customers's homes with units that produce and store hot water outside peak demand periods. Thermal storage heaters will also be connected to the load management system from Siemens. The plan is expected to make it possible to predict overall power demand, eventually leading to automated smart grid management and optimization.

Automated coops are easy to move, thus reducing waste-bred infections.

Automation: Healthy Mobility for Free-Range Chickens

A new control system from Siemens is providing free-range chickens with more comfort while reducing their risk of infection. Now being used in conjunction with mobile coops, the system automatically controls the chickens' daily routine — e.g. feeding, lighting changes, and release from the coop. By facilitating these services, the system makes mobility more practical. Here's why: Chickens like to peck in groups. But their waste quickly makes the ground an ideal place for germs to grow. The solution is to make frequent moves to fresh locations. If moved once per week, the result is that the animals stay healthy without medication. An added benefit is that old feeding sites are completely regenerated in a just few weeks. Between 200 and 1,200 (max.) chickens can live in each mobile coop built by Iris Weiland e.K. Energy for the system comes from solar panels and roof-mounted gel batteries.

Funding Bright Ideas

New Siemens Venture Capital Fund. With an investment volume of $100 million, Siemens' "Industry of the Future Fund" invests in young companies with promising technologies that could revolutionize industrial markets — or even open up completely new markets. The fund focuses its involvement on digitization and software solutions for efficient manufacturing.
Until now, Siemens' venture capital activities have tended to target mature companies. But the new fund supports very recently founded start-ups that have bright new ideas.
The fund is already participating in two firms in the U.S. The first, CounterTack, develops security software that recognizes attacks by malicious software — known as malware — autonomously. Standard protection programs and virus scanners deliver regular software updates to provide protection against new malware. But hours and sometimes days can go by between the first appearance of a new threat and the update. CounterTack's software neutralize such malware quickly and thus provides additional protection between regular security updates.
The Industry of the Future Fund has also invested in the Lagoa company, which makes high-performance cloud-based 3-D visualization software. Until now, this type of software package was expensive and had to be installed on an particularly powerful local computer. By contrast, Lagoa provides cloud-based access to software along with the necessary computing capacity. A user only needs a standard Internet browser.
This approach facilitates industrial applications and makes working on 3-D models easier for geographically distributed teams. In the future, it will be easier for developers in different parts of the world to work together on complex animations in real time.

A new $100 million fund supports start-ups.

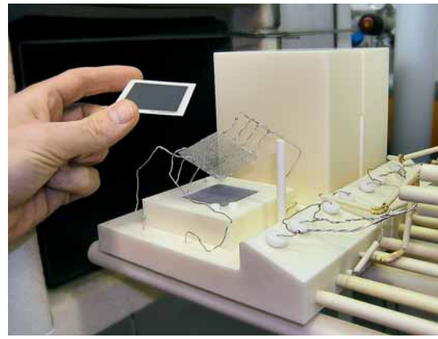
Intelligent Eyes For Automation

A Siemens optical identification system is benefitting from new object recognition functionality. The solution, which is based on a Simatic industrial control system, uses so-called Pat Genius software, which is distributed to licensed customers. Conventional code readers identify objects by registering patterns such as dot matrix codes and bar codes. Pat Genius does this, but also evaluates the camera images recorded by the code readers and identifies whole objects or characters based on their shapes. The system is trained by teaching it the shapes of reference objects. The user shows the system specific forms and it subsequently recognizes these forms on its own. Pat Genius supports up to 2,500 test operations per minute. This Siemens solution is special because it makes integrating object recognition into industrial system controls, such as Simatic, Simotion, and Sinumerik, so simple. Areas of application include quality control, processing machine control, and pick & place robots. Object and character recognition systems are used in virtually all sectors, including the automotive, pharmaceutical, medical technology, and food and beverage industries.

New software learns to see target shapes.

New Electrolytic Cells Could Boost High-Performance Energy Storage

Siemens develops and manufactures electrolyzers that produce hydrogen in PEM (polymer electrolyte membrane) cells. These cells operate at temperatures below 100 degrees Celsius and under high pressure. Now, in a project sponsored by the German Federal Ministry of Economic Affairs, Siemens is also examining high-temperature electrolysis, which promises to be more a efficient process — an important factor for the high-performance energy storage systems of tomorrow. In addition, in the future, chemical synthesis could couple such electrolyzers with methane, for example. In cooperation with their partners, Siemens researchers optimized electrochemical cells that use an oxygen ion-conducting electrolyte as a substrate. The challenge they faced was to limit the effects of aging by using a special electrode material. In an endurance test at 850 degrees Celsius, the researchers observed voltage-related aging that amounted to only 0.2 percent per 1,000 hours of operation. Having demonstrated the long-term stability of ceramic electrolytic cells, the researchers have successfully concluded the project.



Boosting efficiency with high-temp electrolysis.

Siemens is delivering 448 turbines to an Iowa wind farm — the world's largest order for onshore wind energy.

Fresh Wind for the U.S.

Siemens has received an order for 448 wind turbines from MidAmerican, a power company in the U.S. state of Iowa.With a total output capacity of 1,050 megawatts, it is the largest order for the onshore wind-energy sector to date. Each of the wind turbines has an output capacity of 2.3 megawatts (MW) and a rotor diameter of 108 meters. The turbines, which will be installed in five projects, will generate enough power to supply around 320,000 American homes with electricity.

Iowa is one of the leading states in the U.S. when it comes to wind energy. In 2012, wind energy provided about 24 percent of all the electricity generated there. In total, Siemens has already installed around 1.2 gigawatts (GW) of wind-power capacity for MidAmerican. When the current follow-up order is completed in 2015, these wind farms will be able to provide more than 660,000 American households with clean energy. The nacelles and hubs for the wind turbines destined to fill MidAmerican's order are being manufactured at a Siemens plant in Hutchinson, Kansas, a nearby U.S. state. The rotor blades are being produced by Siemens in Fort Madison, Iowa.

Siemens can also report excellent success when it comes to offshore wind power in North America. The company and Cape Wind have signed a comprehensive contract for the first large offshore wind farm in the U.S. The farm will be located off the northeast coast of Massachusetts, 20 kilometers from the island of Nantucket. Siemens will deliver not only the offshore wind turbines but also the offshore service platform. In addition, an agreement was reached concerning a long-term service contract. When it is completed, Cape Wind will have an output capacity of 468 megawatts. Installation and commissioning are scheduled for 2016. Offshore wind energy has great potential for providing coastal areas of the United States with clean electricity in the future. Suitable offshore sites are located along the northern and southern Atlantic coast and in the Gulf of Mexico. A recent study conducted by Navigant on behalf of the U.S. Department of Energy predicts that in the next five years the output capacity of offshore installations in the U.S. will increase to 3.5 gigawatts.

The Door that Recognized its Body

Siemens' Energy, Industry, and Infrastructure Sectors staged their first-ever joint presentation at the 2014 Hannover Fair trade show this Spring. Their exhibits offered a preview of the future of the industries these sectors serve. A highlight was a look at concepts for the production systems of the future.

A vision of the future of automobile production using installation of doors for a VW Golf VII as an example (top right).

Married and then separated. That describes the initial relationship between vehicle doors and bodies. Indeed, the two are first joined in a body shop to ensure that the gap between them is exactly right. But the union doesn't last long. Immediately after this important quality parameter is checked, they are separated. The doors are sent to a paint shop for a coating that matches the color of their body. The only question is: how do the two find each other again — and as quickly and accurately as possible?

The vision: During the painting and door interior finishing steps, bodies and doors recognize each other as if by magic — with the help of radio frequency identification chips. These electronic chips would communicate with one another and thus know which components go together. Scanners would read their data and transmit it to robots that would join the components. The robots might also make decisions to correct errors. For example, if a bore were missing, they would order one to be drilled.

The above description is a vision of the factory of the future, which, in Germany, is referred to as "Industry 4.0" (see *Pictures of the Future*, Spring 2013, p. 19). The concept is based on the future Internet of Things and Services, in which the physical and virtual worlds merge into a holistic system.

"However, it could take 15 years for all of this to happen," says Dr. Dieter Wegener, Head of Technology at the Siemens Industry Sector. Nevertheless, many aspects of Industry 4.0 were on display at the Hannover Fair trade show in April 2014 — more specifically, at the Siemens stand and the Future Forum in Hall 9. One highlight here was a system that knew which automotive model it would need to assemble next. This is important because a major industry trend is that different models are processed on the same assembly line.

The path to Industry 4.0 is being prepared by systems such as Siemens' Totally Integrated Automation (TIA) Portal (*see Pictures of the Future*, Spring 2013, p. 19) and Tecnomatix, which is a product development program that designs and simulates an assembly line. The resulting digital models can also be used to simulate and optimize logistics processes and production throughput.

Use of such systems in combination with Siemens' Simatic IT production software saves time and money. "The time it takes to design a factory from initial concept to assembly hall layout can be up to 50 percent lower as compared to conventional methods," says Anton S. Huber, CEO of Siemens Industry Automation. "Throughput times are reduced by 20 to 60 percent, and material handling costs are lowered by up to 70 percent through optimization of factory layouts in the production planning process."

Such solutions are already being used in the automotive and aerospace industries. The state-of-the-art development techniques utilized by Siemens engineers were also on display in Hannover in the form of the ZEOD RC electric-hybrid race car. The vehicle, which was developed in the virtual world with the help of Siemens PLM Software, is now very much for real and is expected to take part in the 24-Hour Le Mans race.

The principle behind Industry 4.0 is simple, but its implementation is demanding. Every sensor and actuator in a manufacturing process has its own IP address and is thus addressable. This is necessary in order to ensure that customized products can be manufactured in a highly flexible mass production process that reacts quickly to changing market requirements. However, it's not just that product lifecycles are getting shorter; the whole nature of production is changing as well. Intelligent machines and products, warehousing systems, and manufacturing materials are all being linked together via information and communication technologies that cover the entire value chain — from logistics to production, marketing, and service.

At its Service Factory exhibit in Hanover, Siemens presented an industrial production model. The model demonstrated how proper use of data can enable smoother and more energy-efficient production processes. More specifically, the model could be used to project future developments that would serve as a basis for making decisions.

For example, in the future, automotive components will continually collect and transmit data about their condition, and well before a component fails it will ask to be replaced (p. 84). For example, a door-locking system might send a message to its manufacturer to the effect that a replacement part will be needed. All of this is still a long way off, but the initial requirements for it, such as Internet connectivity and error messages issued by onboard computers, already exist. One thing that's still missing is further integration among vehicles and manufacturers and dealerships in order to ensure optimal service.

Error messages will then be issued containing the exact vehicle type and data on where the component should be sent. Orders will then be processed in a factory in which machines configure themselves to accommodate production and delivery of the component. The system will also automatically generate a service center appointment.

What's more, in the future, when something goes wrong in a vehicle, a report will be sent not only to the manufacturer and to the nearest service center, but also to development units. Engineers will thus be able to determine the cause of the problem and take measures to prevent it from happening again. ■ *Harald Hassenmüller*

Electric boats glide noiselessly on the waters of southern Bavaria's Königssee thanks to motors from Siemens.

Quiet Cruising on Königssee

For more than 90 years, electric motors from Siemens have powered boats on Bavaria's Königssee. Built in 1958, the boats' drive systems have been providing silent service for a long time. Soon, the systems will be replaced by replicas of the same model.

Siemens engineer Klaus Hunsicker, 55, is welcomed by innumerable flags as he arrives in Schönau on Königssee (king's lake) in Bavaria. He makes his way through the village's pedestrian zone, passing shops offering traditional Bavarian costumes and souvenirs. The air smells of freshly baked pretzels. As Hunsicker walks, he begins to catch glimpses of world-famous Königssee. He finally reaches the emerald-green lake, which extends through the valley like a fjord, surrounded by steep cliffs and dominated by 2,700-meter-high Mount Watzmann. The lake, which is almost eight kilometers in length and up to 190 meters deep, contains more than 500 million cubic meters of potable water.

Hunsicker is on a special mission. Several new electric motors are needed for the fleet of ships operated by Bayerische Seenschifffahrt GmbH — the lake's transport company. The challenge for Siemens is that the new motors should be the same as the 1958 models, which the company produced especially for Königssee. That's why Hunsicker has come here today. As director of a Siemens repair center, Hunsicker specializes in replica motors, a career that takes him all over the world. In the dockyard next to the lake, Hunsicker meets Michael Brandner, who manages the fleet's 18 electric boats and is responsible for their upkeep.

Siemens motors have been powering electric boats on Königssee since the beginning of the 20th century. Before then, passengers traveled in rowboats steered by boatmen known as "See-Knechte" (lake servants). The electric boat era was made possible by the railroad, which was completed in 1909 but has since been decommissioned. The railway recharged the boats' batteries. Back then, Siemens not only supplied the trains, it also supplied the technology for the Gartenau power plant near Berchtesgaden.

In 1909 the decision to equip the boats with electric drives was not prompted by environmental considerations. Instead, Prince-Regent Luitpold, who ruled Bavaria at the time, feared that the noise created by combustion engines would scare off wildlife in his hunting grounds alongside the lake. That's why he was very much in favor of procuring electric boats that would travel noiselessly on the lake. The lake's electric era commenced with the *Akkumulator,* an electric boat supplied by the Siemens-Schuckert plants. It was followed by additional boats, all equipped with electric motors from Siemens. The boats were a big success, thanks to their reliability, low operating costs, and lack of emissions. Today, the boats are still powered by 110-volt motors manufactured in 1958. The boats have an output of around nine kilowatts and an average speed of 12 kilometers per hour. Each boat travels about 120 kilometers per day of operation, consuming almost 80 percent of its battery capacity in the process.

"We always know how to manage," says Brandner. "Our familiarity with the motors is passed on to each new generation, and we even installed the old motors into our new boats." The boats are serviced in Bayerische Seenschifffahrt's own dockyard, which has been building the vessels since 1983.

However, as a result of the growing number of visitors, the Königssee fleet has repeatedly reached its capacity limit. "That's why none of the motors are allowed to stand still for even a minute," says Brandner, who has been working for Bayerische Seenschifffahrt for the past 25 years.

Brandner leads Hunsicker through the lakeside boathouses until they reach the "patient." It is a typical representative of the Königssee fleet, measuring 20 meters by 3.5 meters. It is handmade out of precious wood. Inside, up to 93 passengers can sit on 1920s-style wooden benches with red cushions made by Bayerische Seenschifffahrt's own upholstery firm. Brandner raises a big lid to reveal the boat's "heart," a Siemens electric motor. Hunsicker's delight at the site of the motor is plainly visible. "You can't buy something like this ready-made," he says. Before coming to Königssee, he held several phone conferences with Brandner, examined old plans and data sheets, and studied photographs of the electric motor's technology.

He believes it's only natural for Siemens to manage its technological heritage — even for small orders. "No other company has the know-how to replicate a 56 year-old electric motor. That makes us special," says Brandner with pride. "We'll once again have a motor that perfectly fits the existing installations. It would be much more expensive to replace the electronics than to replicate the motor. Today, comparably powerful motors are only about the size of a shoe box, so they aren't compatible with the electronics in the existing fleet."

The new electronic systems will therefore be designed for the old motors, which are much bigger than today's electric drives. In addition, the old model motors are less complex than new ones, which is why they can be maintained by Bayerische Seenschifffahrt's own electricians in Schönau. This is an important consideration for the Königssee fleet, because breakdowns have to be quickly taken care of in order to ensure the boats' reliable operation, especially during the peak season when thousands of passengers want to cross the lake every day. That's why a replica of the old motors is an optimal solution for the customer as well as a sensible investment.

> *No other company has the know-how to replicate a 56 year-old electric motor.*

Since preparations must be made before Siemens can submit an offer to Bayerische Seenschifffahrt, Hunsicker quickly gets an overview of the situation and talks with Brandner about the next steps. Because blueprints no longer exist for the motor, one of the old electric drives has to be brought to Hunsicker's repair center, where the motor can be disassembled. Once new blueprints have been made, the replica motor can be built within eight months so that it can be delivered to the customer on time for the peak season. Before Hunsicker drives back to his office, Brandner invites him to get into one of the boats and travel to the pilgrimage church of St. Bartholomä. This trip is an absolute must, because the captain always blows his highly polished trumpet in the middle of the lake to make the world-famous double echo resound at the steep Brentenwand cliffs. Now Hunsicker knows that there was a very good reason for driving all the way to Königssee: Extremely quiet motors will help to preserve a little piece of paradise.

■ *Kerstin Schreiner, Andreas Binner*

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Energy efficiency is the order of the day. It not only helps to mitigate climate change, but is also crucial for maintaining economic competitiveness.
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As increasing amounts of wind and solar power enter transmission networks, it is not just demand for energy that is fluctuating, but also its supply. Siemens has developed neural network-based forecasting software that predicts fluctuations.
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The 2014 World Cup in Brazil is spurring advanced infrastructure solutions. An example is the new national stadium in Brasilia, which is the "greenest" sports arena in the world.
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Intelligent Energy Use | Scenario 2040

Above it All

2040 Researcher and engineer Niklas Meier, whose workplace is near the South Pole, seldom gets visits from his brother Peter. During a reconnaissance flight in an airship, Niklas shows his brother what he's working on. He is establishing a reliable and CO_2-neutral microgrid that supplies power for several research stations. The project is also designed to develop highly efficient and environmentally friendly technologies for the world market.

The Antarctic in 2040. Three research stations must generate their own power. One of the facilities has therefore been tasked with establishing a smart, CO_2-neutral and secure energy supply. In an airship high above it all, two brothers discuss how it works.

"What a view!" exclaims Peter as the airship lifts into the air from the icy ground of a site deep in the Arctic and glides upward. "It's great, isn't it?" responds Niklas. "Even down at ground level you can see how beautiful and awesome the Antarctic is — but only when you're up here can you grasp the true dimensions of this desert of ice and bare cliffs."

At exactly this moment, a short signal tone sounds in the cabin and the airship's ascent comes to a halt. "We've reached our maximum altitude," explains Niklas to his older brother. Throwing out his arm in an expansive gesture, he adds, "Welcome to Antarctica's highest observation platform. I'll be your personal guide for the duration of this flight."

Peter laughs as he enjoys the unique panorama. "Wow, the buildings down there look almost like a small town. I can see that lots of institutes have set up shop all around you," he says as he points to the three research stations that stretch out below them. Niklas agrees. "Yes, they have. One of them is researching ice cores to find out about the development of the climate and the shifting

of the earth's magnetic field. Another institute is hunting for microorganisms that have antibiotic properties. And as you know, my employer is doing everything it can to establish a CO_2-neutral, intelligent, and, above all, reliable power supply for all of us."

Peter nods without shifting his gaze from the view outside the window. "Where else in the world are the conditions for setting up a power microgrid so challenging? If you can succeed here, you'll be able to succeed anywhere. But what does your work look like exactly?" His brother points to the renewable energy plants near the research stations. "Our energy supply is based on wind turbines and solar panels that can stand up to the cold and don't ice up, as well as solar collectors for hot water and photovoltaic panels," he explains. "The power they generate is distributed to all of the research stations. But these sources alone aren't enough to keep the buildings permanently supplied with power."

Peter continues this thought. "Whether it's day or night, summer or winter, there will always be tremendous fluctuations," he says. Niklas nods and says: "Exactly. The research stations have to adjust to this situation and match their demand to the supply." Peter shakes his head. "But in order to do that you have to know far in advance how much power will be available, don't you?" he asks.

Niklas laughs and says, "You're absolutely right — but, as you'll soon see, we don't have to be magicians to do that." He taps a code into his touchpad. The panoramic window of the airship promptly lights up with projections of cross-sections, diagrams, and networks superimposed on the research stations. The projections are adjusted to the brothers' respective angles of vision. Peter is amazed. "What's this?" he asks.

"It's an image of the work we do," says Niklas. "It's absolutely crucial for our power supply to be able to predict how much power we can expect to generate in the future. What's operating here is learning software that is based on neural networks. It compares the weather forecasts for the days ahead, takes seasonal characteristics into account, and knows from experience how much power each research station consumes at various times of the day.

"With the help of these parameters the system is able to predict how much power will be generated over the coming days with an accuracy of plus or minus just a few percent. And by comparing predicted supply with predicted demand, it can also determine on which days we can expect to have deficits."

Amazed by this information, Peter hardly knows which projection he should look at first. "But how do the stations adjust to daily power fluctuations without having it affect their operations?" he asks.

"Our researchers don't notice any of that," his brother reassures him. "On the basis of this information, a smart power network connecting all the stations programs itself automatically. Whether it's the ventilation control system, lighting, water purification, the greenhouses, or sensitive lab technology, this smart grid knows all the energy users in the three stations and their respective degrees of importance," Niklas continues. "The system can therefore calculate how many minutes each energy consuming system can be shut down without limiting its functions. That way it reacts promptly to predicted power deficits."

Peter has just noticed something off in the distance. "Ah, those are hydrogen tanks, aren't they? That answers my question about the storage units," he says. Niklas grins at him. "During the southern summer, when the sun shines almost all day long, we generate much more power than we can actually consume at the time," he says. "We use this surplus power to melt snow and break down water into oxygen and hydrogen through electrolysis. We store the hydrogen in tanks and generate heat and electricity from it with the help of fuel cells in the winter when power is scarce.

"As you can see, we're a more or less CO_2-neutral group, and we have a sufficient supply of energy even on those days when power generation is minimal. My team is now working on integrating the data we've acquired here into even smarter technologies. After all, this isn't the only place in the world where highly efficient solutions are of crucial importance."

Niklas has concluded his special tour. He looks over at his brother and asks, "Do you like it?" "Fantastic!" Peter answers. "It's really a thrill to see what you can create by networking producers, consumers, and this entire process of data analysis." Then he grabs his brother in a headlock, just like in the good old days. "But you're paying a high price by having to run around here all bundled up so you won't freeze, you sissy! Come on, let's land this thing. I've brought along something you're going to like. I actually managed to smuggle it past the greedy dog of the supply ship's captain on the way here." "What is it?" Niklas asks. Peter grins. "I can tell you this much, you're going to need a lot of energy to deal with it," he says. ■ *Sebastian Webel*

Siemens' new headquarters in Masdar, Abu Dhabi, boasts optimal efficiency and sustainability.

Reinventing Energy Conservation

Energy efficiency is the order of the day. It not only helps to mitigate climate change, but is also crucial for maintaining economic competitiveness — not just in countries with high energy costs, but also in so-called energy oases.

With its vast natural gas and petroleum resources, the United Arab Emirates (UAE) is a veritable energy gold mine. Nevertheless, the country is investing heavily in the development of new sustainability concepts. One project is attracting particular notice due to its highly ambitious goals. It calls for the construction of a completely CO_2-free and environmentally-compatible urban settlement in Abu Dhabi. Despite some planning changes and construction delays, Masdar City is still expected to be completed in a few years. Since January 2014, one of the city's buildings in particular has been offering a preview of environmentally friendly and energy-efficient life in the desert — the new Siemens headquarters for the Middle East, which has received LEED Platinum certification for its outstanding energy efficiency.

"The Siemens building is designed like a box within a box, so to speak," says Dr. Roland Busch, CEO of the Siemens Infrastructure & Cities Sector, whose portfolio includes the building systems used in Masdar City. The building's highly efficient airtight inner facade lowers thermal conductivity. Thanks to the use of sustainable materials and, more importantly, Siemens technologies, the energy demand of the new Siemens headquarters is equivalent to that of a low-energy building in Germany. The outer shell consists of metal panels that are aligned with the changing position of the sun throughout the day, ensuring sufficient shade. At the same time, glazed courtyards reflect sunlight into the building's public spaces below and thus into the building's offices as well. The atrium allows warm air to escape via a chimney effect. In addition, condensate from the air conditioning system is used for irrigation.

Desert Climate. "It's truly a sustainable building — it was awarded LEED Platinum certification in a climate where temperatures often rise above 45 degrees Celsius," says Busch. "That makes it unique and shows just what technology is capable of today."

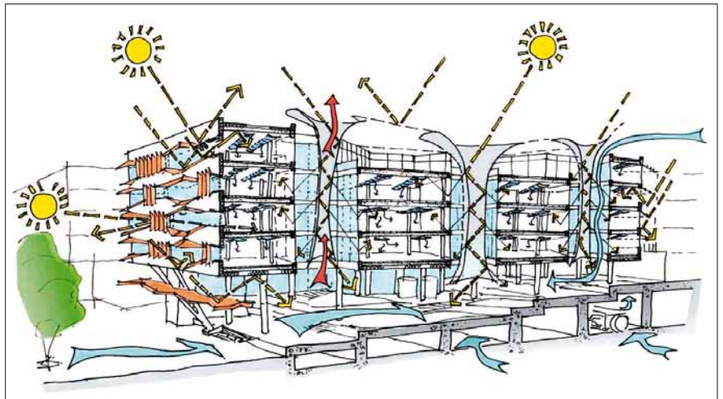
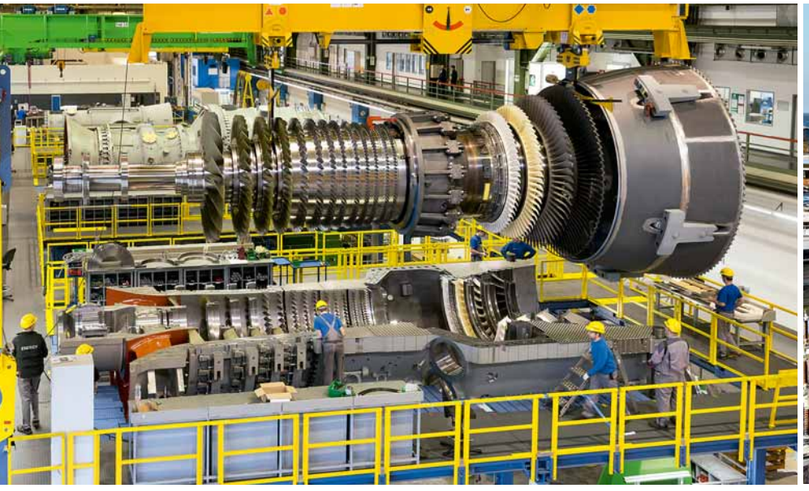


Illustration copyright: Sheppard Robson

Horizontal and vertical shading concepts prevent sunlight from heating Siemens' headquarters in Masdar. An average of 35 percent of the building's heat-insulating facade is made of glass, with an even higher percentage around the edges and on its northwest side. This design ensures optimal exploitation of daylight. Glazed courtyards reflect sunlight into the building's offices, while the atrium allows warm air to escape via a chimney effect.

Still, one question remains: If the UAE is so rich in cheap energy, why are billions being invested in projects like Masdar City and in complex buildings such as the new Siemens headquarters? One must look to the future to understand the answer. Over the long term, only limited quantities of natural gas and petroleum will be available even in the Middle East. Countries are therefore investing in their future to ensure continued prosperity after the age of fossil fuels comes to an end.

In many industrial countries the problem is more urgent. European economies in particular are under tremendous pressure due to rising energy costs. Ironically, among the key cost drivers in this area are the efforts of European countries to develop concepts for battling rapidly evolving climate change. This applies in particular to Germany because of its energy transition. The country's extensive promotion of renewable energy has caused prices for a kilowatt-hour (kWh) of electricity to skyrocket.



Whether it's a world-record gas turbine for a power plant or a smart grid in Denmark (center), intelligent energy use is the order of the day.

Flat glass manufacturer f | glass (right) uses 500-degree Celsius waste heat to produce electricity.

German industry now pays roughly 15 euro cents per kWh, which is 24 percent higher than the European average[1]. A look across the Atlantic is enough to make German companies queasy, as shale gas deposits in particular have led to extremely low electricity prices for American industry (currently around five euro cents per kWh). This price is unmatched by any other country, although China and India are close behind in the electricity cost rankings (see chart).

In addition, the replacement of many old coal-fired power plants in the U.S. with new gas-powered plants led to an approximately six percent decrease in CO_2 emissions in 2012. Meanwhile, in Germany, emissions from electricity generation rose by around three percent during the same year.

Conservation's Competitive Advantage. Industrial companies in Europe have realized that energy conservation is a key factor in competing with regions where electricity costs are significantly lower. One conservation method involves intelligent load management systems, such as the one used by garden tool manufacturer Gardena. The company uses a system that automatically regulates power use in a manner that prevents load peaks. Another example is offered by a flat-glass manufacturer that uses production waste heat to generate electricity (p. 40).

Intelligent building technologies can lower energy demand by as much as 40 percent, and clever solutions are also available to effectively put energy guzzlers in the steel industry on a "diet." Such measures not only lower energy demand and emissions; they also substantially reduce operating costs. The steel industry could actually accomplish a lot more here, according to Dr. Alexander Fleischanderl, Head of Technology and Innovation Management and ECO Solutions at Siemens VAI Metals Technologies in Linz, Austria. "If the industry were to use all currently available Siemens technologies for conserving energy and raw materials and minimizing CO_2 emissions, it would be doing practically everything that makes sense economically and is physically possible," says Fleischanderl. (p. 34)

Examples such as these illustrate that there are many ways to increase energy efficiency in industry, some of which can also boost a company's competitiveness by reducing costs, which in turn safeguards jobs. However, much more could be done to use energy efficiency as a lever for increasing competitiveness. Research projects such as one in which Siemens is working with Volkswagen and the Fraunhofer-Gesellschaft to optimize the movements, and thus the energy use, of automotive industry robots (p. 38) illustrate that energy efficiency will become the order of the day in the future.

Still, additional legislation will be required to achieve a sustained long-term reduction in energy demand. Such legislation is on the way in the European Union. For example, a new directive stipulates that in the period from 2014 to 2020 EU member states will have to achieve annual energy savings equal to 1.5 percent of their annual average energy demand between 2010 and 2012.

This increase in energy efficiency is crucial for the future, because the cleanest and cheapest energy is the energy that's never used. Here to, competitiveness will be very important in the future because it's nearly impossible to predict the development of prices for electricity and other forms of energy. Moreover, rising prices must not be allowed to lead to the transfer of value-creation chains to places such as the U.S., where energy is very cheap.

The German government has recognized this risk and plans to amend Germany's Renewable Energy Sources Act and pass a new law that would go into effect on August 1, 2014. Possible measures will include focusing on less expensive technologies, utilizing a bidding process to set subsidy levels from 2017 on, and switching to a binding direct marketing system or a system in which all electricity consumers make a reasonable contribution to financing renewable energy sources. The reform is meant to slow further increases in electricity prices while retaining the goals of the energy transition.

A Fluctuating Energy Market. It's already clear that wind and solar power in particular will result in growing fluctuations in the energy market over time. That's because the use of such sources will cause not only energy demand but also its supply to fluctuate. A key question here, therefore, is what share of energy from renewable sources can be allowed into the grid without destabilizing it, while ensuring low prices. Although it seems theoretically possible to supply an industrialized country such as Germany with electricity obtained solely from renewable sources (p. 22), it's not clear how much that would cost. What is clear is that effective energy storage solutions and flexible and highly efficient gas-fired power plants would be required, as this would ensure that the grid could be replenished within minutes when wind or sunshine fail (p. 16). Such gas plants might also be powered by hydrogen or methane in the more distant future. These gases would be produced in an environmentally friendly manner through electrolysis and methanization using surplus power from wind and solar facilities.

The renewable energy challenge: Not only will energy demand fluctuate in the future — so will supply.

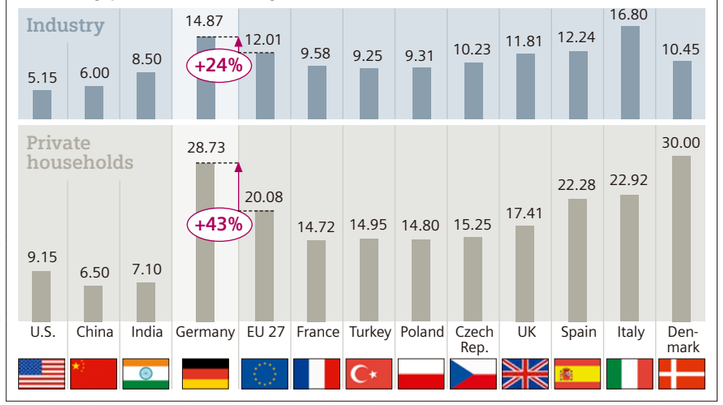
Devices that consume energy will also have to adjust demand in near-realtime to fluctuating electricity supplies in order to ensure grid stability. An example of how this might work is on display in Europe's biggest smart grid project on the Danish island of Bornholm. There, building heating units, boilers, and heat pumps automatically adjust their operation to electricity supply without reducing the comfort of residents (p. 26). However, this won't be sufficient for the future, when the supply of energy from renewables will have to be planned several days in advance in order to ensure an appropriate response time to weather-related fluctuations.

Siemens has therefore created forecasting software based on neural networks to make such fluctuations and thus future electricity markets more manageable (p. 18). "The software can forecast electricity generation from renewables a few days in advance and then compare the data with anticipated demand during the same period," says Dr. Ralph Grothmann from Siemens Corporate Technology in Munich. "This makes it possible to predict situations marked by surplus electricity or supply bottlenecks, and then plan accordingly. Surplus power can thus be marketed more effectively. The software also enables us to manage conventional power plants as back-up systems more efficiently, and thus at a lower cost." These examples offer hope that Europe can make a virtue of necessity, or at least know the challenges it faces if European industry is to continue competing on the world market, even as its energy costs remain high. The efforts made here might even lead to the creation of new products and solutions that will actually give Europe a competitive edge in the post fossil-fuel era. In any case, nothing should be considered impossible when it comes to energy efficiency. If nothing else, the Siemens building in Abu Dhabi offers proof of that. After all, who would have thought just a few years ago that a building in a desert climate could be as comfortable and efficient as a low-energy building in Germany?

Sebastian Webel

High Electricity Prices Are Putting a Strain on Industry and Private Households in Germany

Electricity prices[1] in Germany and other countries in 2013 (in €ct/kWh)



Source: Eurostat (December 2013), BdEW, EIA

1) Electricity price for German industry (incl. tax) for 160 MWh/a to 20 GWh/a; for companies >100 GWh/a the EEG surcharge is only 0.05 €ct/kWh.

The new power plant (right) will not only be an architectural milestone. It will also be the home of a record-breaking turbine from Siemens.

The New Face of Efficiency

A transparent tower is rising in the heart of Düsseldorf. But rather than housing offices, the structure will be part of the most efficient gas-fired power plant on Earth. When it enters service in 2016, the plant will break records for efficiency — thanks in part to a vast district heating system.

At Lausward, part of the Düsseldorf harbor area, a landmark is taking shape. "The building will be visible from many places in the city, so it deserves a special design; one that creates a distinctive identity," says Gerhard Wittfeld, Managing Director of kadawittfeldarchitektur, the architecture firm responsible for the project. "And that led to the idea of giving the building a sort of rhythm, which is generated by its steel frames and the gaps between them."

If this sounds like one of those faceless office towers that cities are famous for, it's not. Instead of carpeted offices or lofts, this one-of-a-kind structure will house a combined cycle gas turbine power plant (CCGT). To be more precise, it will be home to the world's most efficient and thus most environmentally-friendly power plant of its kind; and it is being built by Siemens.

The plant's glass-enclosed power source will open up to the city. "We want our architecture to make people aware of the sources of energy that are driving our city," says Wittfeld. The client is the utility company Stadtwerke Düsseldorf (SWD), which wants to use the plant as a reliable energy source for the city and, considering its prominent location in the middle of Düsseldorf, to also create a new urban statement.

"In contrast to many other regions in Germany, the population here is continuing to grow," says SWD Lead Project Manager Rainer Tröger. "Together with the high demand for power and heat from the regional economy, that means a growing need in the future, and the new power plant addresses that demand. At the same time, we want to get the most out of our fuel."

The power plant is designed with precisely that goal in mind. Due to begin supplying electricity and heat in 2016, the plant will be outfitted with a combination of a gas turbine, a steam turbine, and additional waste heat recovery — and it will try to break three world records at once. Here's how:

- At the heart of the plant will be the latest Siemens turbine generation: the SGT5-8000H. Its output is equivalent to that of 22 jumbo jet engines, and it weighs as much as an Airbus A380 with full fuel tanks. In combination with a downstream steam turbine (Siemens SST5-5000), the Düsseldorf power plant will provide an electrical output of approximately 595 megawatts (MW) in a single block, which is a first.
- In another first, the electrical efficiency of the power plant will be over 61 percent — exceeding the previous record of 60.75 percent attained by the Siemens-built "Ulrich Hartmann" CCGT plant in the Bavarian town of Irsching (see *Pictures of the Future*, Fall 2011, p. 96).
- In an additional process, the plant's waste heat energy will be used to supply district heating for the city of Düsseldorf. The 300 MW of thermal energy that will be extracted for this purpose will set a worldwide record for the amount of power harvested by a single gas turbine generating unit.

Full-Load Output in 30 Minutes. When it goes on line, the "Block Fortuna" plant, as it has been christened by Stadtwerke Düsseldorf, will burn its natural gas fuel with an overall efficiency rate of 85 percent. Every year, the plant will therefore emit approximately 700,000 fewer metric tons of CO_2 than the worldwide average for electricity generation plants. That corresponds to the amount of CO_2 produced by approximately 350,000 passenger cars, each driving 15,000 kilometers a year. Top-class features like these are enough to get both experienced engineers and laymen excited.

However, by themselves, these achievements will not be enough for the plant to operate cost-effectively. In order to supply energy profitably, it will have to operate at full capacity. To understand why, it is important to bear the following in mind: From a technical point of view, efficient gas-fired power plants like this one represent the ideal technology for an economy that is using a steadily growing share of renewables to meet its energy needs, which is what Germany plans to do while shifting to a sustainable energy supply. After all, fluctuations in power generation as a result of changing winds or cloud cover must be quickly compensated for, and the Block Fortuna power plant will be a true champion in this department. It will be able to reach full generating capacity within just 30 minutes of starting up.

The plant will reduce annual CO_2 emissions by 700,000 metric tons — equivalent to those of about 350,000 cars.

Unfortunately, however, electricity from CCGT plants is hardly cost-effective in Germany, because of current market conditions. At the moment, in fact, despite Germany's plans for greener energy production, because of low raw material costs and the extremely low prices for CO_2 emission certificates, coal, rather than natural gas, is the most common fuel now being used to generate electricity. "In Germany, many gas-fired power plants therefore produce electricity only 1,000 to 2,000 hours per year. But to operate cost-effectively, at least 3,000 hours are normally needed," explains Olaf Kreyenberg, head of European power plant sales at Siemens Energy, who is responsible for sales activities at the Lausward project.

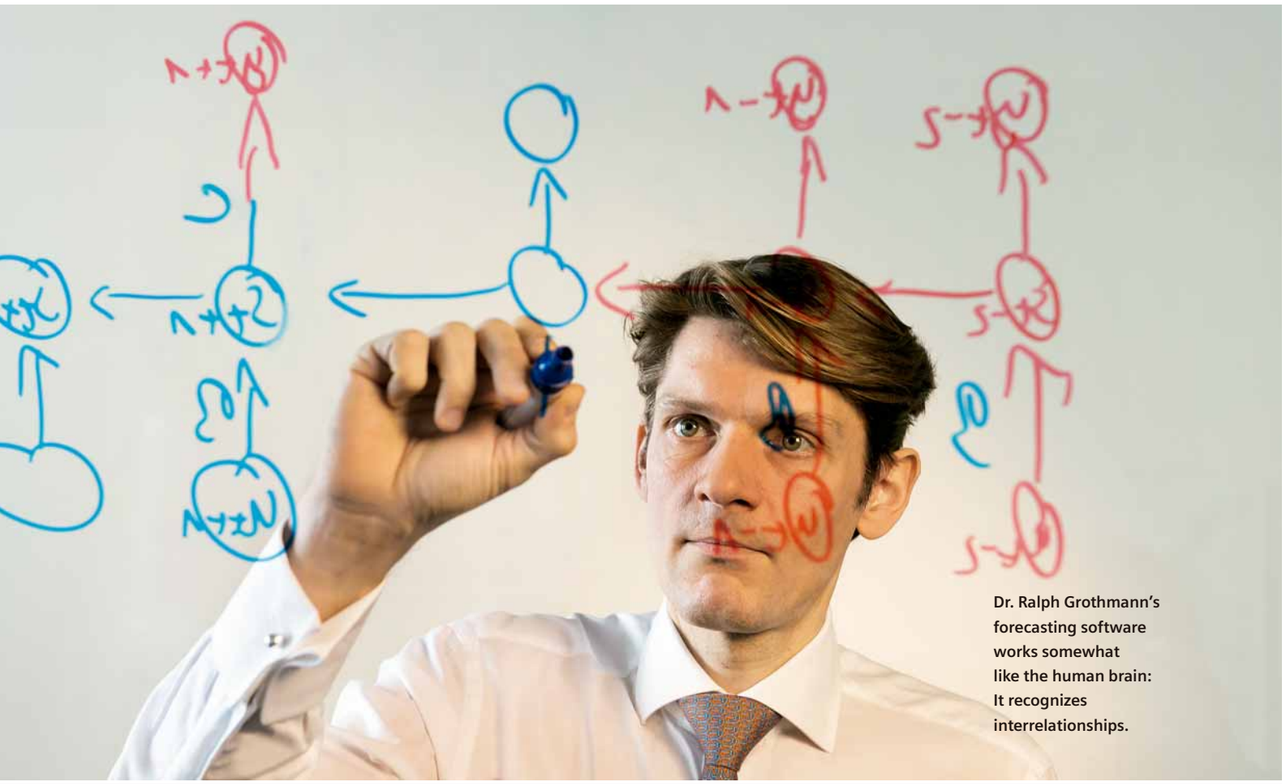
How can the Lausward power plant escape the fate of other similar plants? "To operate a CCGT plant profitably in Germany, you currently need more than just electricity production," Kreyenberg continues. "You need guaranteed purchases of the process heat to boost the operating hours into an economical range. And that's precisely what you have in Düsseldorf, thanks to one of the largest district heating systems in Germany. As a result, the plant is expected to reach a utilization rate of approximately 5,000 hours per year."

Adds Tröger: "We have the perfect conditions here. The plant is being built on a site that's been used for power generation since the 1950s — so a large part of the infrastructure we need is already present, such as the district heating system and a direct connection to a 110-kilovolt grid owned by SWD. Heat supply in particular will continue to play an important role here in the future."

District Heating Makes the Difference. Despite the economic efficiency that is expected to drive Block Fortuna's success, the plant is by no means a blueprint for the CCGT market in Germany as a whole. "A power plant of this kind with reliable customers for both heat and electricity, with a large installed district heating system, is possible at only a few locations in Germany," says Kreyenberg.

Nevertheless, the Lausward example illustrates that CCGT power plants can, under certain conditions, be operated profitably even in the current regulatory environment. And to ensure that the plant will deliver profitable and record-breaking performance for as long as possible, Siemens and Stadtwerke Düsseldorf have decided to continue their partnership after SWD takes charge of the plant. "In years to come, we want to help our partners in Düsseldorf always get the best out of their plant — for example, by raising its efficiency even further through innovations," says Kreyenberg.

The Lausward plant will thus be a system that can respond flexibly to the requirements of the energy market in the future . And that's a characteristic that architect Gerhard Wittfeld and his firm keep coming back to. "Regardless of the angle from which people will look at this building, they will always have a sense of flexibility; of the rhythm of the power plant," he says. But despite the plant's name, the architect, the plant operator, and Siemens are not leaving *fortuna's* success to Lady Luck. Thanks to top technology, they expect it to be a showpiece of a power plant — in more ways than one. ■ *Sebastian Webel*



Dr. Ralph Grothmann's forecasting software works somewhat like the human brain: It recognizes interrelationships.

A Better Forecast for Renewables

As increasing amounts of wind and solar power enter transmission networks, it is not just demand for energy that is fluctuating, but also its supply. Siemens has created neural network-based forecasting software that predicts fluctuations, thus helping to increase the efficiency of electricity markets.

Everything was simpler in the past. Power plants were distributed throughout countries and their output was adjusted according to energy demand. Power plants used calendars and weather forecasts, among other means, to predict the power needs of regions and large production plants.

Today, the situation is more complicated. Depending on the weather, wind farms and solar parks produce varying amounts of electricity, and conventional power plants must make up for fluctuations. The greater the share of fluctuating renewable energy sources, the more difficult it becomes to manage power supply — an issue that affects power suppliers and grid operators alike.

To ensure the grid remains stable, it must always be supplied with as much electricity as is taken from it. If a power station or a major consumer breaks down, the energy supply is either increased or decreased, as the case may be, to prevent power outages. Every power plant is required to supply certain amounts of positive and negative controlling power. However, it will become increasingly difficult to keep the grid in balance in the future — especially in Germany, which is in the midst of an energy transition and plans to greatly boost the share of renewables in its power mix (p. 22).

How should this new situation be handled? How can power companies keep the grid stable, provide a secure supply of energy, and still remain profitable? Dr. Ralph Grothmann, a researcher at Siemens Corporate Technology (CT), says the answer is to improve planning through better forecasting. "If you knew how much solar and wind energy would be available in the days ahead and also had regional demand forecasts, you could manage conventional power stations with great foresight, plan sufficient energy supply to counterbalance transmission losses, and buy energy at favorable terms on the power exchange," he says.

With this vision in mind, Grothmann and his colleague Dr. Hans Georg Zimmermann have developed forecasting software known as the Simulation Environment for Neural Networks. SENN uses artificial neural networks (i.e. computational models) that are similar to the ones in the human brain (see *Pictures of the Future*, Fall 2011, page 53). These networks can be trained to recognize interrelationships so that they can make forecasts. "The cool thing about neural networks is that you don't have to fully analyze and understand a problem in order to make a forecast," Grothmann explains.

For example, if you wished to depict a solar park with an analytical model, you would need to calculate how much electricity a solar panel produces on the basis of the incident solar radiation and other environmental factors, such as temperature, wind speed, and humidity. If some of the panels happened to block the sunlight from reaching others, this would need to be taken into account. Only then could the model use the weather forecast to predict the solar park's output at its precise location.

Training with Data. Neural networks are handled very differently. They are trained using past data — in this case, weather forecasts and the solar park's electricity output for these times. The weather data doesn't have to come from the solar park's location; it can be supplied by a nearby weather station. The program's task is to predict how much solar power will be produced on the basis of the weather data. At first, the software doesn't know what effect the various parameters will have, so its forecast will deviate significantly from the solar park's actual output. During the training phase the program repeats this process thousands of times to minimize the difference between a forecast and actual values. As this happens, SENN changes the weighting of individual parameters to become more and more precise.

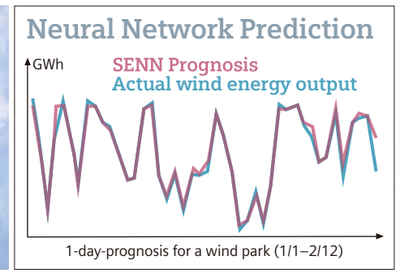
Using empirical data, the system learns to forecast renewable power generation to within about seven percent.

Originally developed over 20 years ago, SENN is currently used, for instance, to forecast raw material prices and the price of electricity over 20 day periods. It can accurately predict the best purchasing day two thirds of the time. Siemens has used SENN since 2005 to buy electricity at times when prices are lowest.

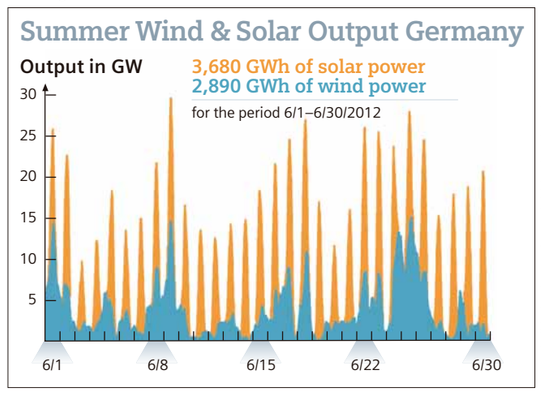
With the boom in renewable energy sources, Siemens recognized that SENN forecasts would have great potential for the energy industry. For example, forecasts of the amount of electricity that will be fed into the grid by renewables allow network operators to plan the use of additional power stations or the need for balancing energy. Operators of wind farms and solar parks can use the forecasts to schedule maintenance work during times when energy systems are expected to produce a lower yield, to sell the expected amounts of electricity at more favorable terms, and to plan future income.

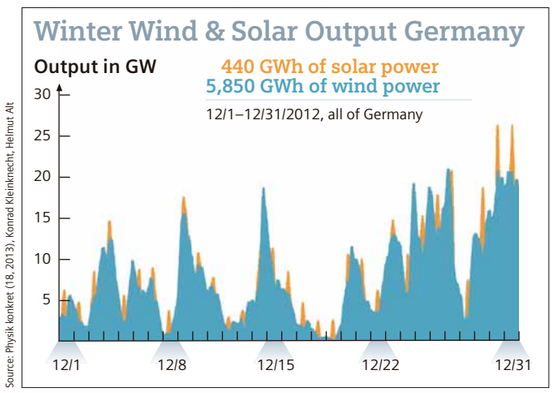
A SENN model is now being tested on data from a large offshore wind farm in Denmark. The model uses forecasts for wind speed, temperature, and humidity to predict the farm's electricity output for the next three days to within 7.2 percent. For example, if the system forecasts an output of 100, the actual value would be between 92.8 and 107.2. "The accuracy of the forecast depends mainly on the quality of the data," says Grothmann. "All in all, we can predict the weather fairly accurately three days in advance."

Siemens Energy offers SENN production forecasts as part of its monitoring and control solutions for power facilities that use renewables. For instance, SENN is being used in South Africa at two solar parks, each with 50 megawatts of output. The software enables the power companies to meet the network



Although sunshine and wind are unreliable, software from Siemens is learning to forecast the resulting electricity yield.





Source: Physik konkret (18, 2013), Konrad Kleinknecht, Helmut Alt

operators' forecasting need regarding the amount of electricity that will be fed into the grid. SENN can predict the solar parks' electricity production for every hour of sunshine in the next five days to within about seven percent.

A second model for solar parks is now being planned. It will advise operators about ways to handle grimy solar panels. Dust can reduce panels' power production by up to 15 percent, but cleaning them costs money too. "If an operator knows that enough rain is on the way to wash away the dust, it won't have to send in a cleaning crew," Grothmann explains. The new software will resolve this issue by using environmental factors such as aridity, wind, and rain to forecast how much dust will cover the panels.

Forecasting Demand. Demand forecasts are the second major application of SENN in the energy market. They enable major consumers to buy electricity at favorable terms

Forecasting software can improve efficiency.

or schedule operations so as to avoid periods of peak demand during which they may have to pay stiff fines. Energy suppliers can use regional forecasts to plan electricity purchases and power plant operations. For instance, Swiss network operator Swissgrid uses SENN to plan electricity purchases in such a way that transmission losses are taken into account as huge amounts of power flow from Germany or France to Italy (see Pictures of the Future, Spring 2012, page 99). Because Swissgrid has to offset such losses, it purchases electricity on the spot market up to 36 hours in advance, for about €48 million per year.

Swissgrid used to estimate demand on the basis of calendar and weather data and information supplied by network operators in neighboring countries. But SENN has reduced the forecasting error from 11 to 10 percent, enabling Swissgrid to save hundreds of thousands of francs per year.

SENN generates very accurate demand forecasts with an error rate of only three percent. On this basis, it can directly predict the transmission losses. To do this, it monitors the hourly development of demand in the region to which the electricity is to be transmitted. It also examines current power flows, the amount of energy being generated from renewable sources, weather forecasts, and the water levels in pumped-storage electrical power stations.

Thinking Holistically. Individual forecasts are a first step toward a future energy market in which almost all factors — production, demand, price, and transmission — are in flux. All of these quantities in the system are interdependent; as a result, they should be examined holistically. For instance, if wind facilities increase energy production, conventional power stations would need to produce less power, which might reduce the price of electricity. Depending on demand, the wind energy would be transmitted either northward or southward. This, in turn, would change the need for balancing energy to offset transmission losses. "The better the interaction of these parameters can be predicted, the more efficient the entire system will be," says Grothmann.

This is an area where the SENN neural network shines. Because it doesn't use analytical relationships but instead learns to recognize interrelationships from the behavior of all parameters, its forecasts already encompass the interdependencies. "One of the ways in which we use SENN is to determine the price of electricity from a wide variety of interacting parameters, such as the development of the price of electricity and other raw materials, the development of demand, and the cost of CO_2 emission permits. This makes our software unique," says Grothmann.

Today, an energy supplier with several power plants could already use SENN to purchase natural gas cheaply and optimally adjust electricity output to forecasts for the price of CO_2 permits and electricity. In the future, a network operator could provide the energy supplier with forecasts regarding demand and the anticipated need for balancing energy. These predictions would, in turn, be based on the production and demand forecasts supplied by other partners. All of this would make the rather dizzying volatility of energy markets easier to handle, because all of the players could adjust their activities in advance to accommodate developments affecting other market participants.

Christine Rüth

Efficiency: The Key to Meeting Global Energy Demand

In its *World Energy Outlook 2013,* the International Energy Agency (IEA) has forecast that, taking the effects of current energy and climate-protection targets into account, global energy demand will increase by one third between 2011 and 2035. Around two thirds of the increase are expected to take place in Asia, excluding South Korea and Japan. Demand for oil is expected to rise by 27 percent, demand for natural gas by 46 percent, and for coal by 17 percent. In 2035 China will be the world's largest importer of oil, while India will be the largest importer of coal. By contrast, the IEA believes that the U.S. may be able to cover all of its energy needs from its own sources by 2035, thanks in part to its shale gas deposits.

Despite these developments, the IEA nevertheless estimates that half of the new power stations built worldwide by 2035 will use renewable sources of energy. These sources will cover 31 percent of global electricity needs by 2035, compared to 20 percent in 2011. In order to achieve higher yields and more efficiency, it would make sense to distribute capacities not only within each country, but also internationally. This could be done EU-wide, for example. According to calculations made by Siemens, transferring the planned expansion of solar energy systems from the UK and Germany to Spain and Italy and of wind power from southern Europe to the North Sea and the Baltic Sea would, by 2030, reduce the amount of photovoltaic capacity needed by 39 gigawatts (GW) and of wind energy capacity by 16 GW even though total power output would remain the same. Although this transfer would require the building of additional power lines, the total investment needed would nevertheless drop by $45 billion.

According to the IEA, deep-sea drilling and the discovery of unconventional oil and natural gas deposits are leading to changes in the global distribution of energy reserves. In addition, this development is creating new regional differences in energy prices, with Europe and Japan being the main losers. German consumers are already paying two to three times as much for electricity as customers in the U.S.

Due in part to fracking, natural gas prices in the U.S. have dropped to one third of the levels in Europe and one fifth of the levels in Japan. Energy costs can have a big impact on a company's competitiveness. This is especially the case in energy-intensive sectors such as the chemical, steel, aluminum, and paper industries.

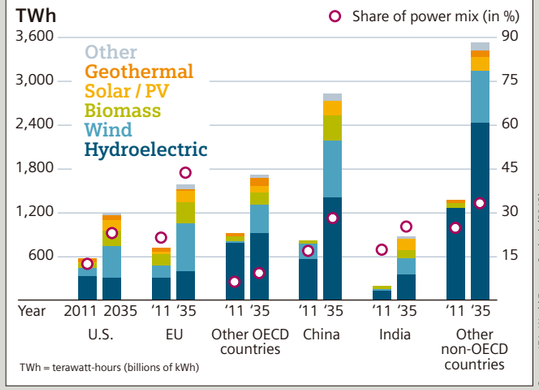
As a result, gains in energy efficiency are becoming increasingly important. In many cases, the high purchase price of energy-efficient industrial equipment, motors, and lighting systems can be recouped within a few years through cost savings. In 2012 the amount of energy needed to produce a unit of GDP declined by 1.5 percent worldwide. In the U.S. it dropped by almost 4.5 percent, while decreasing by four percent in China. "Energy efficiency is absolutely crucial if you want to remain competitive," says IEA Chief Economist Fatih Birol.

The IEA forecasts that regions such as China, India, and Africa will achieve the biggest improvements in energy intensity by 2035. The IEA estimates that the efficiency measures that are currently being discussed by governments would lead to additional savings of 910 million tons of oil equivalent (Mtoe) by 2035. The EU's energy efficiency directive stipulates that between 2014 and 2020 member states must reduce the average amount of end energy sold by 1.5 percent annually compared to the average amount sold between 2010 and 2012. According to the German Energy Agency (dena), countries can require energy supply companies to achieve the energy savings target; alternatively, they can use instruments such as subsidies and energy taxes. Several countries, such as the UK, France, and Denmark, have already introduced national energy efficiency requirement systems. In Denmark, grid operators are required to meet established energy-savings targets. To do this, they are implementing energy efficiency measures either at their customers' premises or through selected energy service providers.

Other examples of how the savings can be achieved include more stringent efficiency standards for trucks and buildings in the U.S., measures for improving the energy efficiency of buildings in China and Europe, and tougher standards for electrical appliances such as TV sets, dishwashers, and lamps in Europe. In February 2013, U.S. President Obama announced that he wanted to double the GDP-to-energy rate by 2030. According to the U.S. Energy Information Administration (EIA), increasing the energy efficiency of buildings will play a key role in achieving this target. Important tools here include tax incentives and tax vouchers for the installation of energy-efficient building systems.

Meanwhile, the Chinese province of Hebei has enacted a new energy efficiency standard that was developed by dena in cooperation with the Center of Science and Technology of Construction (CSTC), which is under the control of the Chinese Construction Ministry. One of the high-rise buildings in the province already meets the new standard. The ministry aims to use this provincial standard as a basis for introducing a nationwide energy standard for new buildings. "The building consumes around 75 percent less energy than new buildings usually do in China," says Stephan Kohler, Chief Executive of dena. *Sylvia Trage*

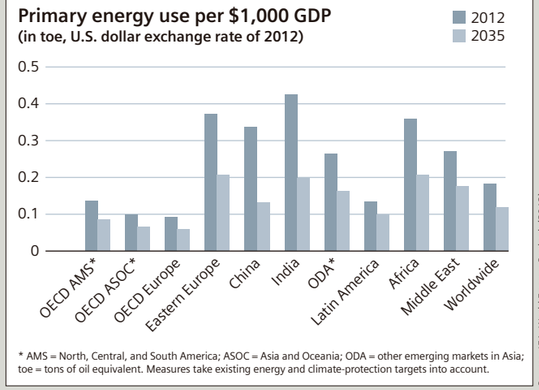
Comparative Energy Mix 2011-2035



TWh = terawatt-hours (billions of kWh)

Source: IEA, World Energy Outlook (2013)

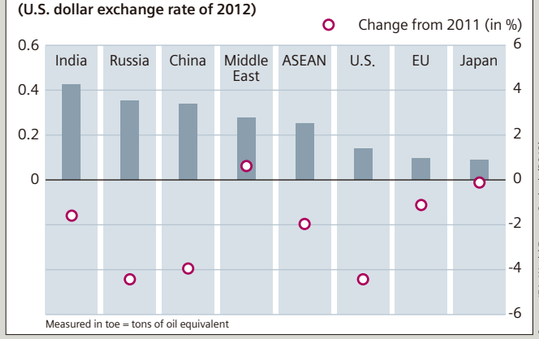
Comparative Efficiency 2012-2035



* AMS = North, Central, and South America; ASOC = Asia and Oceania; ODA = other emerging markets in Asia; toe = tons of oil equivalent. Measures take existing energy and climate-protection targets into account.

Source: IEA, World Energy Outlook (2013)

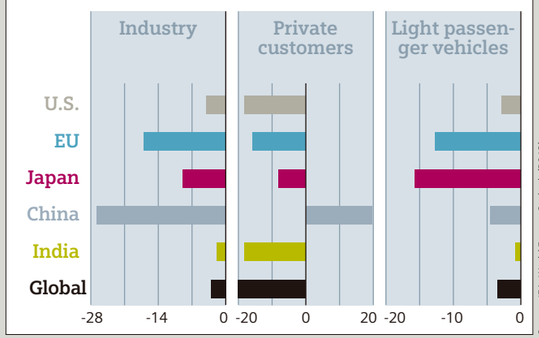
Energy Intensity Change 2011-2012



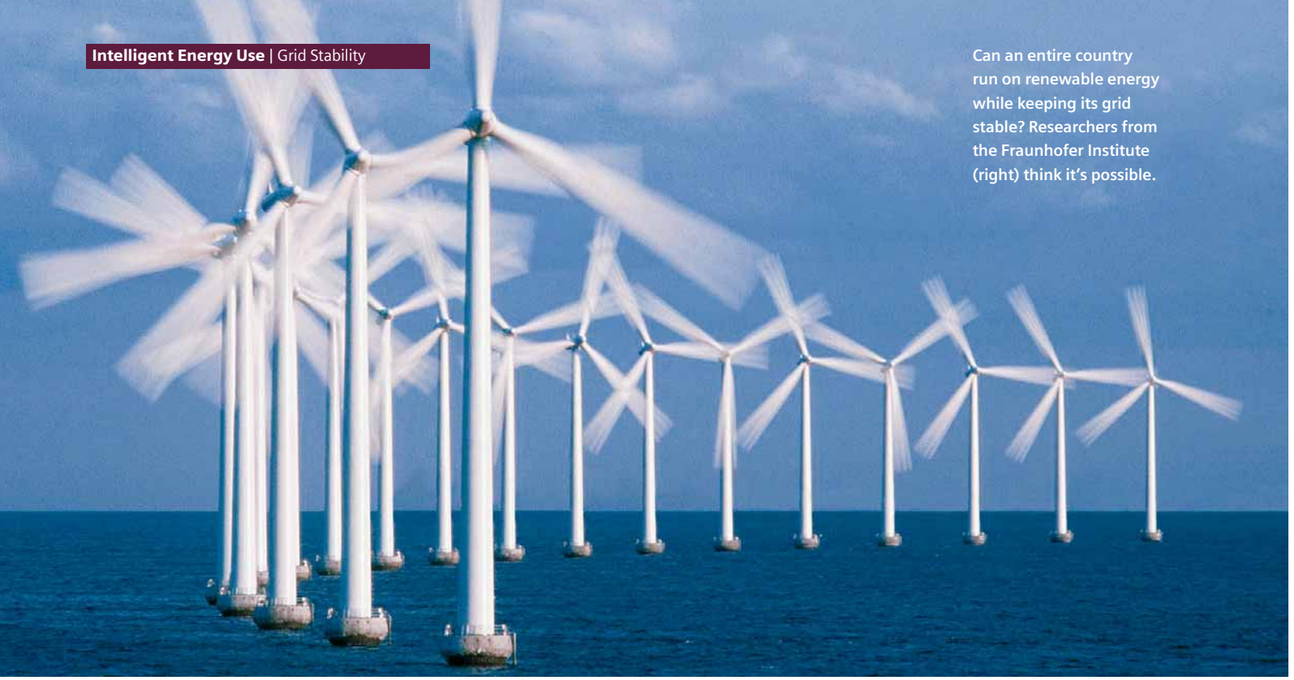
Measured in toe = tons of oil equivalent

Source: IEA, World Energy Outlook (2013)

Energy Intensity Change 2005-2012 in %



Source: IEA, World Energy Outlook (2013)



Can an entire country run on renewable energy while keeping its grid stable? Researchers from the Fraunhofer Institute (right) think it's possible.

Running on Renewable Energy

A research project funded by Germany's Federal Ministry for the Environment shows that if renewable energy sources were networked with storage systems and standby power plants, they could secure the country's power supply in the future. How much that would cost is another story.

February 1, 2050, is a good day for German electricity consumers. The breeze off the north coast is blowing so strongly that offshore wind farms and the wind turbines on land are running non-stop. Since it's a sunny day, photovoltaic modules, which are mostly located in the south, are also working at peak capacity. On monitors in a central control room, engineers can see from a diagram that, in total, an average of 80 gigawatts (GW) of renewable electricity is being generated, with a midday peak that is as high as 120 GW.

In this scenario, renewable electricity produces enough energy to supply industry, trade, commerce, and households throughout Germany with power derived exclusively from wind and sunlight. The largest consumers are Berlin, Hamburg, and the municipalities in the Ruhr district. But thanks to new transmission lines, densely populated areas such as these have no problem.

If at some point there isn't enough wind or the sun isn't out, this scenario includes standby power plants that operate on methane and biogas systems — but they certainly aren't needed today. Staff members in the control room decide that this is an ideal day for replenishing storage systems across the country with excess electricity and using power-to-gas systems to produce methane gas that can be fed into the natural gas lines or turned into electricity again.

Can an infrastructure based almost completely on renewable energy provide grid stability and dependability in the same way that fossil-fuel plants do today as demand rises and falls? In other words, are technical solutions up to the task of balancing natural fluctuations in the wind and the sun?

In a joint project called "Combined Power Plant," scientists addressed these questions, and came up with an answer. "It is possible to provide balancing power using 100 percent renewable sources. The crucial factor is a power control system for decentralized plants that is active, intelligent, and accurate to the nearest second," say Siemens researchers Dr. Philipp Wolfrum and Dr. Florian Steinke. That was the finding that emerged from simulations conducted by Siemens Corporate Technology (CT) and its partners from the scientific and business communities (see box p. 23).

A Lot of Wind and Sun. In principle, say control system engineers, the renewable energy plants of 2050 really could maintain stable frequency and voltage in the German power grid, assure reliable service, and also produce enough load-balancing energy to always provide precisely the electrical output that is needed at any given time. In their project, they assumed that wind energy would account for the lion's share — in this case 60 percent — of power production. Approximately a fifth would come from photovoltaic systems, and ten percent would come from bioenergy. Hydropower and geothermal energy would account for the remaining ten percent.

The model of this energy supply system was based on the assumption that annual power demand would be of approximately the same as it is today, that is, about 600 terawatt-hours (TWh). The model included additional consumers such as electric cars and new storage technologies, and it also took into account the increases in energy efficiency that are expected by the German federal government, as well as optimizations of industrial systems and processes and possibilities for demand management.

The model also assumed that the Network Development Plan of the German federal government (for the year 2032) will be implemented, so that, for example, future offshore wind farms will be connected to the grid, and the high-voltage direct current lines needed to transport the resulting electricity across large distances will be built — mainly from the north to the south of the country.

On the basis of weather and electricity demand data from 2007, the researchers estimated the power generation and demand of the whole country for every hour of a year, with a spatial resolution of 100 meters by 100 meters. Experts at the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) conducted extensive analyses of locations, including the possibility of local generation, to identify the spatial distribution of new wind and photovoltaic plants. Load flows in the grid result from renewable energies fed into it, electricity demand, including load management, and the use of power plants and storage systems.

But that by itself is not enough to demonstrate that a power supply is reliable and secure. These days, grid operators have to guarantee what are called "ancillary services." In addition to maintaining stable frequency and voltage, these include congestion management and, in the event of an outage, the rapid restoration of supply. The resulting virtual combined power plant must show that it can provide these services at all times, that it balances supply and demand, and that it can keep the frequency at a steady 50 Hertz, the prevailing value in Europe. This is essential, because deviations can lead to the collapse of electrical networks.

Using simulations, the project's partners were able to determine production peaks, surpluses and deficits, and subject the system to extreme situations, such as the failure of individual lines. The results indicate that voltage and frequency stability, congestion management, and service reliability would be achievable in the envisioned future system.

However, to meet these objectives, some of the project's general technical conditions would have to be adjusted. For example, in the future, inverter-based generators at photovoltaic plants and wind power plants could provide load-balancing power more quickly than is currently demanded by today's systems. This would provide additional stability for the grid and thus compensate for the inevitable reductions in power generation that occur as wind speeds moderate or drop to zero.

For every hectare and every hour of the year, researchers determined the whole country's power generation and demand.

But the project's partners didn't limit their studies to simulations — they also examined feasibility issues in a subsequent field trial. For this experiment, they connected four biogas, 36 wind, and 66 photovoltaic plants across Germany. These plants, with a total capacity of approximately 80 megawatts, were managed from a control center in Kassel. In this renewables-based combination power plant, the partners tested the approaches they had come up with and demonstrated that renewable energy plants can be managed as a power pool to meet the technical requirements for supplying load-balancing power.

"Thanks to their modern inverters and converters, solar and wind power plants allow even more freedom of action than synchronous generators connected directly to the grid," say researchers Wolfrum and Steinke. "They allow voltage, phase position, and frequency to be adjusted very effectively. All in all, we were able to demonstrate that system stability was preserved, and how it was preserved." . But the researchers added one proviso: The plan's envisaged paradigm shift in the supply of electric power can succeed only through a massive expansion of storage technologies. This is the only way to offset seasonal fluctuations in wind and photovoltaic output, they said.

Many Storage Units Needed. In view of this, Siemens scientists therefore also used simulations to calculate how to optimize the type, spatial distribution, and use of storage units and flexible generators in the context of their long-term planning. The constraint for these optimizations stipulated that all loads must be perfectly covered at every instant. Today, utility companies use pumped storage reservoirs as buffers. Their efficiency rate is a very high 80 percent, but capacity is nowhere near adequate for the storage of large quantities of energy. Today's pumped storage power plants could supply Germany with energy for barely half an hour — and

Combined Power Plant 2: A Major Partnership

The Combined Power Plant 2 project, which is known in Germany as Kombikraftwerk 2, was funded by the German Federal Ministry for the Environment and ran from 2010 to 2013. The project's partners included Siemens, Enercon, SMA Solar Technology, SolarWorld, Deutscher Wetterdienst, the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES) in Kassel, Leibniz Universität Hannover, and the Renewable Energies Agency. In simulations and field tests, these organizations examined how a power generation and distribution system based on renewables could function and what ancillary services would be needed. A key part of the project was how to ensure grid stability.

there aren't enough suitable locations to build more.

As a result, power-to-gas plants will play a crucial role. These plants would use excess renewable electricity to decompose water into its constituents (hydrogen and oxygen) in the chemical process known as electrolysis. Carbon dioxide (CO_2) would then be added to produce methane gas. The methane would then power gas and steam turbine power plants directly — and be converted back into electricity with an efficiency rate of more than 60 percent. Methane can replace natural gas, and it can be fed into the public gas grid. The study pointed out that the German natural gas grid can easily handle the storage needs of renewable energy surpluses.

Biomass power plants will be an important part of the renewable energy economy.

Wind and solar power stations would be supplemented by biomass plants in addition to gas-fired power plants. Both can respond quickly and flexibly and can thus be used to balance out fluctuations in power generation. However, researchers have calculated that these power plants must be numerous enough to collectively be capable of reaching approximately the maximum load in Germany. Even if existing gas-fired power plants could be used for this purpose, this would still require the construction of plants capable of generating tens of additional gigawatts, which would be a problematic investment if the plants were needed only a few hundred hours per year (p. 16).

"In the winter, for example, when there is no wind and the sky is overcast, they would jump in as a reserve and guarantee a supply of power for everyone in Germany," says Wolfrum. "Another challenge lies in storage management. If I know when it will be cloudy or calm, I can fill the various types of storage systems a few days in advance in the right order and discharge them in the optimal way when power is needed." The project's partners have also calculated what a national renewable energy system would need in terms of added grid construction. Their data show that the grid would have to be expanded only a modest amount beyond the current Network Development Plan of the German federal government. In view of their results, they are convinced that Germany really could be supplied with power from 100 percent renewable sources if the renewable power plants, storage systems, and biogas plants were intelligently integrated.

"We believe the current costs for primary energy in Germany can be lowered to practically zero over a period of 40 years."

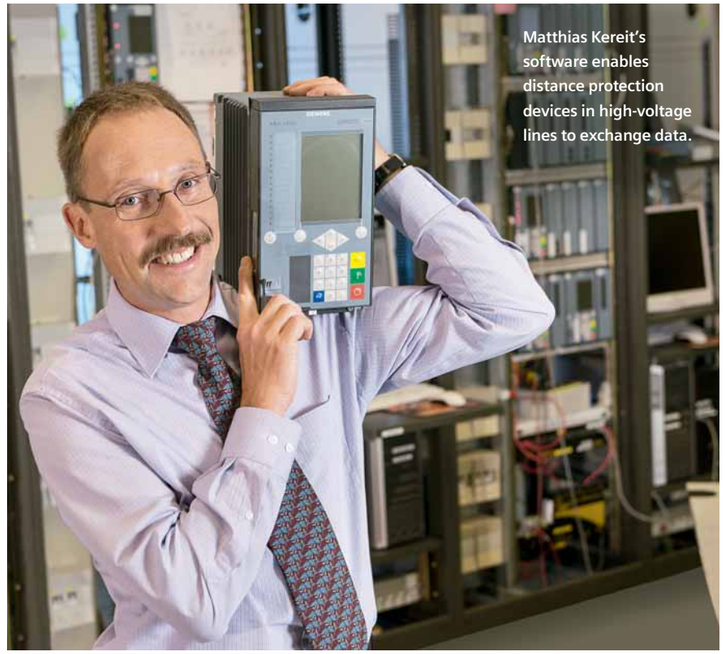
Monitor, Regulate, Optimize. A prerequisite for this is a powerful communication infrastructure that would allow decentralized renewable energy plants to be monitored and managed in real time. Although such a system would become more complex as a result of this, Steinke says it would be manageable "if you perfect the forecasting and the calculations regarding plant usage. The secret of success is the right mix of renewable plants and the application of optimization techniques and management methods to their operation."

In sum, the crucial characteristic of this grand plan isn't renewable energies. What would have to change is mainly the structure and organization of power generation and distribution. "The shift to a sustainable energy supply is possible if the grid with all its components is expanded, a power storage system is built, and the general framework of the balancing power market is adjusted. That's because right now energy sources that fluctuate can't take part. Since you can only predict a short time in advance when renewable power will be fed into the grid, correspondingly shorter bid periods and lead times will be needed," say Wolfrum and Steinke.

Although it may be difficult to examine the individual components of a 100 percent scenario like this one from a business management point of view, the cost to the economy as a whole appears clear to Professor Hoffmann, head of the Fraunhofer Institute's IWES in Kassel. "We believe the current costs of fossil primary energy in Germany — €83 billion per year for oil, coal, and gas — can be lowered to practically zero over a period of 40 years," he says. "According to our calculations, the break-even point will be reached in 15 to 20 years — the point at which the costs for the expansion of renewable energies and the purchase costs for fossil energy will, when taken together, be less than today's primary energy costs."

Moreover, the analyses of IWES researchers comprise not only the electricity sector but also heating and transportation. The experts also see potential in electric mobility, passenger transport, and heavy goods traffic, such as trolley trucks. According to their ideas, heat pumps should cover about 75 percent of the requirement in the low-temperature range, and increasing use should be made of power-to-heat technology in the industrial sector. Furthermore, they say, power demand could be reduced by 25 percent with efficiency measures, including building insulation and the installation of better heating systems.

■ *Evdoxia Tsakiridou*



Matthias Kereit's software enables distance protection devices in high-voltage lines to exchange data.

Instant Analytics

Matthias Kereit is one of Siemens' 2013 Inventors of the Year. His inventions focus on preventing power outages. His latest brainchild could soon make it possible to identify which phase in a line is at fault — a development that would help to stabilize tomorrow's two way smart grids.

No one likes to have a high-voltage power line outside their front door. However, the need for electricity transmission systems is increasing, especially since more and more energy from renewable sources is now being generated far from consumers and has to be transmitted and distributed over long distances. To better exploit transmission capacity, energy suppliers often build pairs of overhead high-voltage lines, with each line carrying three separate cables. Monitoring these lines, which can be hundreds of kilometers long, requires them to be equipped with distance protection devices at their starting and termination points. The devices, which are about the size of a shoe box, are fitted with a microprocessor, relays, and interfaces for communicating with a control center, usually via fiber optic cables.

Short circuits can occur if branches brush against a line, or even if an insulator gets dirty. In such situations, the line has to be shut down instantaneously. Distance protection devices detect short circuits by measuring current-voltage ratios and using the resulting data to calculate impedance, a process that helps to determine the type and location of the problem. However, this can sometimes result in false alarms. "Electromagnetic couplings occur between parallel-running lines, which means a short circuit on one line might trigger a false alarm on the line next to it," explains high-voltage switching specialist and Siemens inventor Matthias Kereit. This can lead to a disastrous chain reaction. That's because it takes only 20 to 40 milliseconds to shut down entire high-voltage lines after registering a short circuit.

With this in mind, Kereit came up with the idea of allowing the protection devices at each end of a high-voltage line to communicate with one another via fiber optic cables. Such a data exchange would help to evaluate the causes of problems and disruptions. In such as setup, the protection devices would exchange information on their current status. A program Kereit developed processes the data to determine whether a given line is operating, or how many power transmission poles have been affected by a short circuit. The information collected by analyzing these and other parameters could be used by the protection devices to make a decision as to whether a line should be shut down completely or only partially. For example, if a short circuit affected just one phase of a line, only that phase would be temporarily shut down until the electric arc was extinguished.

Reversing Current Flow. Kereit's program has yet to be used, but the chances are good that it will be implemented in the next generation of protection devices. "Such programs will become more important as power networks are expanded into smart grids," says Kereit, who works as a developer in the Smart Grid division of the Siemens Infrastructures & Cities Sector in Berlin. One reason why the programs will become more important is that power lines will soon have to carry electricity not only from its source to the consumer but also the other way around. In other words, more parallel lines will have to be laid in order to accommodate the increasing need for power transmission systems.

Kereit has been working on electrical engineering issues ever since he joined Siemens in 1992. He studied electrical engineering with a focus on telecommunications at the University of Applied Sciences Deutsche Telekom, which today is part of the University of Applied Sciences in Berlin. Many of Kereit's 21 inventions, which are protected by 40 individual patents and 20 IPR families, involve improvements to protection devices and earned him the title of Siemens Inventor of the Year 2013. "The development of protection devices brings together many different electrical engineering disciplines, such as power engineering, measuring technology, and digital signal processing," Kereit explains. "It's a field that allows me to use a lot of my expertise in telecommunication systems as well." Kereit enjoys rowing in his free time, especially on long trips out on the water. His longest rowing trip to date was an eight-day journey from Berlin to Hamburg.

■ *Katrin Nikolaus*

At a test site with 1,900 participating households Maja Bendtsen monitors her power use by smartphone, Michael Andersen's heating starts up automatically, and Erik Rasmussen has to start his manually.

Island Laboratory

There's more to sustainable energy than just saving electricity. That's why the EcoGrid pilot project on the Danish island of Bornholm is using Siemens technology to determine how electricity demand can be adjusted to match supply.

Cutting electricity use doesn't always save power. "When I was growing up in Bornholm, my parents sometimes urged me and my brother to take long hot showers and turn the heaters up in our rooms," recalls Maja Bendtsen, 34, an engineer. But Bendtsen's parents had a good reason for their "wastefulness": wind. Back in the early 1980s, when a stiff breeze blew across this Danish island on the Baltic Sea, the wind turbine on the Bendtsen family's property turned especially fast. The result was a sudden surplus of energy and a big incentive to run the electric boiler.

This childhood experience stimulated Bendtsen to appreciate the concept behind "EcoGrid," which, with its 21 million Euro budget, is the biggest smart grid project in Europe. Bendtsen is the onsite manager of the project for Bornholm's local power company, Østkraft. As part of the project, some 1,900 households — almost a tenth of the island's homes — were equipped with newly developed smart switching devices from Siemens and IBM in 2013. Every five minutes, when they receive updated kilowatt-hour prices, the devices determine how much electricity is available. Depending on the data, the devices switch electric heating systems and heat pumps in private homes on or off automatically

The principle behind the project is simple. The price of electricity fluctuates in accordance with the volume of renewable energies. Smart control units calculate how to manage energy demand cost-effectively. As a result, electricity customers save money — and that's not trivial in a country whose end customers pay the highest electricity prices in Europe. "But that's not the most important factor for the electricity supplier," says Bendtsen. "EcoGrid is primarily designed to help manage power demand intelligently in the era of environmentally friendly electricity. If we use more energy when there's a surplus, that helps to avoid overburdening the electricity network. If too little power is available, energy use is reduced, and Østkraft buys additional electricity from the mainland."

For years, wind energy has played a key role on Bornholm. In fact, almost half of the island's energy demand is covered by wind turbines with a peak output of 30 MW. In Denmark, wind energy accounts for 30 percent of the total energy supply. And this percentage is set to grow. By 2020 this small kingdom plans to draw about half of its electricity from renewable energy sources such as wind, photovoltaics, and biomass. By 2035 that percentage is expected to reach 100 percent, and by 2050 Denmark should be independent of fossil energy. Bornholm is an appropriate test case; it's a closed system, yet it is representative of the rest of the country in terms of economy and demographics.

To date, imbalances have been compensated for by the "Bornholm Cable," which connects the island with the grid on the Swedish mainland. According to need, power is exported or imported via this cable. However, the future goal is to use the energy produced here as locally as possible in order to avoid the further expansion of transport capacities, such as high-voltage transmission lines.

Test Case for Europe. Because this situation applies to all of Denmark, Bornholm has become the country's renewable energy laboratory. But this field trial is also relevant for Europe as a whole. Indeed, plans call for a fifth of Europe's energy to come from renewable sources by 2020. That's why Brussels is financing part of the EcoGrid pilot project, which began in 2011 and will run until 2015.

The only question is: are end customers going along with the plan? To find out, the project's initiators — Østkraft, Energinet.dk, the Technical University of Denmark, Siemens, IBM, and a dozen others partners from ten European countries — organized the 1,900 private households into four groups. The first group will serve as a statistical control group. These households received only a smart electric meter that precisely keeps track of their energy use. The second group can see online how much energy they are using and how much it costs — and can change their behavior in response.

The third and fourth groups have been equipped with automatic control units. The former uses a system from Siemens Smart Grid and Building Technologies Divisions that controls electric heating systems and boilers. The fourth group has a similar technology from IBM that controls heat pumps. "We expect the kinds of power control units being tested here to become a standard element of the future smart grid," says Andreas Arendt, who manages Siemens Smart Grid Division's activities in the EcoGrid project.

Arendt's colleague from the Building Technologies Division, Werner Ziel, believes the solution he has developed for the EcoGrid project will be a key element for the smart buildings of tomorrow. "We've succeeded in efficiently integrating smart grid functions into automatic building management systems, thus meeting customers' needs with regard to comfort, energy savings, and reduced energy costs," he says.

Living Laboratory. One of the persons in the Siemens group of test households is Morten Kjær Andersen, who lives in a bungalow on the coast south of Rønne. In a gray box in his home's entry area is a computer that receives the current price of electricity per kilowatt-hour at five-minute intervals. On the basis of this information, the probable development of electricity prices, and the customer's preferred temperature, the Siemens system calculates the best way to proceed. For example, if the price of electricity rises at noon or in the early evening, the system can decide to switch on the electric heating system earlier, when power is cheaper than it is expected to be later in the day.

"Every day I watch the heating system switch on automatically," says Andersen. He appreciates his lower electric bill, but he also hopes that this development will make the islanders' lives more attractive. "In the past, 50,000 people lived here; now there are only 40,000. If we want to realize the vision of a 'green island' on Bornholm — with renewable energy sources, electric cars, and environmentally friendly agriculture — that might help to make the island a more attractive place to live. The EcoGrid project is a part of this vision."

Wind turbines with a peak output of 30 megawatts cover almost half of Bornholm's electricity needs.

Maja Bendtsen not only manages the project but also participates in it. She uses an app on her cell phone to monitor power use in her house. A graph shows her that the heat pump, which is controlled by IBM, has just been switched on. Because power is inexpensive at the moment and her family will come home soon, as usual, the heat pump is warming up the house. "We've entered a command online that the temperature in the living area should be 20° Celsius starting at 6 p.m. on weekdays," she says.

Of course EcoGrid is still just a demonstration and research project. The control units are only being used for the electric heating systems, boilers, and heat pumps. Dishwashers and washing machines, for example, cannot be easily integrated into the system, because they don't speak the same digital language. The devices that are suited to the project are mainly those whose operation is flexible. That includes heating systems, because the exact time when heating is on is less important than a constant pleasant temperature. In the future, solar cells and electric vehicles will be integrated into the system, but even the success achieved to date is impressive. "If we use the data we have already accumulated from the Siemens houses to calculate how much energy was used during periods of peak supply," says Per Lund, the Chief Engineer at Energinet.dk, "we can already conclude this technology can help the Danish power system to integrate renewable energy sources and to operate in balance."

The interim results also clearly show that automation is the best solution. That has been demonstrated by the behavior of the group of households that manually switched appliances on or off based on electricity prices provided over the Internet. Those households hardly reduced their electric bills at all. "At first it was fun to follow our power use on the Internet," says Group 2 participant Niels Erik Rasmussen. "But in the long run it was just too much effort."

Rasmussen's opinion reflects experience in other energy markets, such as the U.S. For example, in 2008 researchers from the Xerox Research Center provided labels for appliances in Californian test households to inform owners about the cost of electricity at various times of th day. But people continued to use their appliances whenever they needed them, rather than at the times when power was cheapest. "If we want to stabilize the electric grid, energy demand will have to be adjusted automatically," says Professor Jacob Østergaard from DTU Technical University. "The electric bill will then shrink by itself. Customers will only need to enter their preference settings."

Østergaard has built a replica of the control room of the Østkraft electric company at his university. "In theory, we could intervene in the power grid," he says. "However, we've deactivated these functions; we only want to collect measurements." His projects include not only EcoGrid, but also a network of about 50 refrigerators in supermarkets. When the frequency in the grid decreases, the cooling units are automatically switched off. After the frequency stabilizes, the cooling units are switched on again. Either some or all of the units can react together, depending on the degree of fluctuation in the grid.

Learning from Bornholm. Another research project further supports the island-wide introduction of EcoGrid's technologies. Until 2012 engineers carried out a study called "Edison" on the island together with grid operator Energienet.dk and Siemens, to investigate how electric cars and hybrid vehicles could help to store surplus energy and return the energy to the grid. The study was a success, but it has not yet been implemented. One reason for that is that there are only around 20 electric vehicles on the island. "We hope that will change. Our goal is to integrate electric vehicles into a concept for balancing the electric grid," Østergaard says.

Siemens is also refining its technology. On the Dutch island of Texel, the local energy cooperative has started an initiative with 300 households that, like EcoGrid, aims to use energy when sufficient amounts are available. It was launched in January 2014. Siemens is supplying an energy management system that helps to calculate the price per kilowatt-hour on the basis of electricity availability. Bornholm is setting an example. "The EcoGrid project demonstrates that every customer can help balance the supply and demand of regenerative energies — without freezing or sweating," says Arendt. ■ *Hubertus Breuer*

Thanks to energy improvements, Vellinge saves six million kWh of electricity per year and emits 2,000 metric tons less CO_2.

Secret in Sweden

Vellinge, a small municipality in Sweden, is saving money while benefiting the environment. The secret of its success: A partnership between local government and a global company.

The small town of Vellinge is in the southwestern corner of Sweden, straddling a peninsula that juts out into the Baltic Sea. It has white sandy beaches and luscious green meadows. The nearby Öresund Bridge connects the Danish capital, Copenhagen, with the Swedish city of Malmö. Beyond the bridge, wind turbines turn in the rough wind. "A large part of our municipality is just a few meters above sea level," says council member Lars-Ingvar Ljungman. "That's why we want to contribute as little as possible to climate change."

The municipality has taken this concept to heart. Since 2005 its 33,000 inhabitants have been investing in "green" building technologies that exploit the full energy savings potential of its municipal facilities. The aim is to save water and energy, reduce costs, and cut CO_2 emissions. Vellinge also wanted to recoup investments in cutting-edge technology as fast as possible through lower energy costs. But to achieve this goal it quickly became obvious that a powerful partner would be needed. Vellinge decided on Siemens, and its experiment was launched.

"We conducted detailed studies of all the town's public buildings and their systems, including heating, ventilation, and lighting," says Louise Johansson, an energy engineer at Siemens Building Technologies in Malmö. "We then made specific recommendations for improving energy efficiency." The first measures were implemented gradually, because Vellinge first wanted to find out how the partnership would develop. All of the measures were financed by means of energy performance contracting deals with Siemens (see box), a model that allows initial investment costs to be repaid through energy savings over a predetermined period of time.

To date, the partners have modernized 43 buildings with total floor space of over 100,000 square meters, including the town hall, administrative buildings, schools, retirement homes, and indoor swimming pools. To save energy, the partners insulated roofs and replaced old oil-fired boilers with heat pumps. Fluorescent lamps and outdoor lanterns containing mercury were replaced with energy-saving LEDs. The lighting systems in schools and daycare centers now automatically adapt themselves to the intensity of daylight and to room occupancy. Water-saving mechanisms were installed in toilets and water faucets. Heating, ventilation, and air conditioning systems were also examined. "We've replaced old exhaust air systems with modern ventilation systems that ensure heat recovery," explains Johansson. The temperature in the buildings is now automatically regulated; thermostats ensure that the air is always as warm as desired. The buildings' users receive energy-related advice regarding the optimal use of light, electricity, and water.

Eight years have passed since the partnership began, but new projects are still being initiated. As a result, energy efficiency measures in 50 additional buildings, including residential and commercial properties, are now in progress. The community saves around 6,000 megawatt-hours (MWh) of energy per year, which is equivalent to about a 30 percent drop in energy demand since the project began. Vellinge now emits around 2,000 tons less CO_2 per year than it used to — about as much as 740 cars emit in a year of average use — and in some respects it has surpassed expectations. The community also saves around €500,000 per year. Current projects promise to achieve additional reductions of 4,710 MWh, 1,100 tons of CO_2, and €470,000 per year. Experts estimate that twelve years from now even the newest of the measures will have paid for themselves.

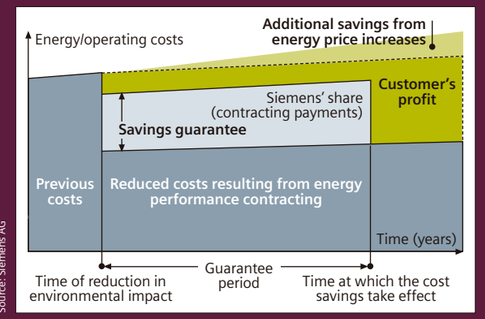
A multi-building monitoring system from Siemens ensures that additional potential is still being discovered and exploited. Numerous measuring points in the community's buildings supply data concerning energy flows to Malmö's Advanced Operation Center, around 12 kilometers away. "From here, we can even remotely optimize systems," says Anders Andersson, who works in Malmö center, where Siemens software evaluates the data in order to determine and improve the systems' efficiency. "We continuously monitor energy use, energy costs, and CO_2 emissions so that customers can achieve or even exceed their targets. From Malmö, we can also find additional savings potential and decide whether further measures should be taken," he explains.

In recognition of this successful partnership, in 2012 Siemens received the Energy Service Award, which is presented by the European Energy Service Initiative (EESI), an EU-funded project that promotes energy performance contracting at the European level. The secret behind the partnership's success is simple: close long-term cooperation in which both parties continuously address energy optimization opportunities.

Vellinge is proud of what it has achieved. "Maybe we can serve as a role model for other communities in Sweden, or even throughout Europe," says councilman Ljungman. "Although we began to implement these measures successfully early on, we're not planning to stop!" ■ *Nicole Elflein*

Investments that Pay for Themselves

Siemens' energy-saving contracting for building technology is a combination of consulting, installation services, and financing. Thanks to this formula, customers do not need to make any initial investment; they simply use energy savings to pay the installments. Worldwide, Siemens has modernized more than 5,200 buildings this way, with more than €1 billion in savings and more than ten million tons of CO_2 reductions. Additional current examples: Modernized ventilation systems are enabling BMW Group Germany to save around 5.5 million kilowatt-hours of electricity per year at its four German plants. Siemens converted control cabinets, replaced fans and electric drives, and installed new frequency converters and cables. The measures were funded by Siemens Financial Services. The resulting energy cost savings are being used to recoup the investment. Similarly, the Reinhard Nieter Hospital in Wilhelmshaven, Germany is benefitting from an energy-efficient cogeneration plant. Siemens also guaranteed to reduce CO_2 emissions by around 4,130 tons and energy costs by €550,000 per year. The hospital is using these savings to repay the financing costs. Another winner is the Bremerhaven-Reinkenheide Clinic, which modernized its air conditioning and ventilation technology in order to increase the energy efficiency of its buildings. New systems from Siemens Building Technologies began reducing energy use at the clinic from the very first minute they entered service. The clinic has since reduced its energy costs by 35 percent while using the savings to cover leasing payments.



Energy performance contracting benefits climate and budgets.

Siemens automation technology is helping Jorge Heireman run a more efficient wine production business.

Tasting Success

The Chilean wine industry is a global winner. But even as competition grows, automation solutions from Siemens are helping one producer discover the taste of success.

The palm tree in the courtyard may give the impression of warm weather, but it is actually a bitterly cold day in August. The winter sun bathes the courtyard of the Santa Rita winery in pale light. Soon the sun will disappear behind the snowcapped mountains. Down here, south of Santiago de Chile, the soil is fertile and the local wines are becoming increasingly popular on the global market. "Only the prices are not yet where they should be," says Jorge Heiremans, the Chief Operating Officer at Santa Rita. "Our product is excellent, but we nonetheless have to pay attention to every peso. If we don't, we'll quickly lose our competitiveness."

Santa Rita's most important cost factors are human resources and energy. Because the booming copper industry is attracting many workers, wages in Chile are increasing, including those in the winemaking field. Well-qualified workers are rare and expensive. And in Chile electricity isn't cheap either. In general, cooling accounts for 80 percent of the energy consumed by Chile's wine industry. But to many people's surprise, Santa Rita manages to do almost entirely without air conditioning in its storage halls. "We've built adobe walls," says Heiremans. "This traditional material is an ideal insulator, and it keeps the coolness inside. Besides, we have programmed the gates so that they automatically open at night and let in the cool air." Thanks to these features, the temperature in the storage halls remains stable at 15 degrees Celsius. But human resources are still the more important cost factor. "We are increasingly automating simple processes. An investment in new technology often pays for itself after just one year. That's why we're paying more for reliable automation solutions so that we don't lose time and money because of technical defects and the like," Heiremans adds. Five years ago, a harvesting machine was used at Santa Rita for the first time. Today six such machines are in operation. Around 300,000 bottles rattle through the filling system every day, guided automatically with the help of a Simatic controller from Siemens. The wine crates are stacked with the help of a Siemens automation system. "Today we have fewer jobs, but they are higher-quality jobs. In other words, we've got fewer packers and more electronic technicians," says Heiremans. "By becoming more efficient we can grow. And in the long term that will create more jobs too." ■ *Andreas Kleinschmidt*

Siemens technologies manage water, power, access, and security systems at the Mané Garrincha stadium.

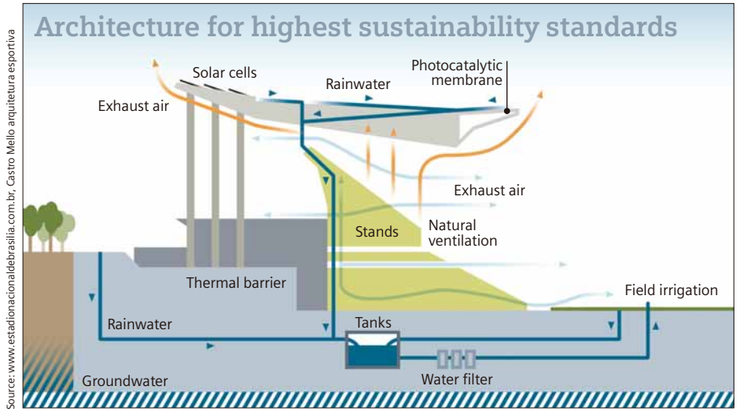
A Star among Stadiums

Major events, such as the 2014 FIFA World Cup in Brazil, are catalysts for investment in modern infrastructure solutions. One such investment, the Estadio Nacional Mané Garrincha in the capital city Brasília, is the "greenest" sports arena in the world.

The old must make way for the new. And in Brazil's capital city of Brasília the 40-year-old multipurpose Mané Garrincha stadium has given way to a resplendent replacement. Construction of the Estadio Nacional Mané Garrincha — a mammoth project built on the foundations of its predecessor — began in June 2010. But with an allotted construction time of only two years, 15,000 workers had to be hired in order for Latin America's second-largest soccer stadium to be built on time. The architecture of the new stadium is influenced by the buildings of Oscar Niemeyer, and it seamlessly continues the modernistic trend in Brazilian architecture. With a seating capacity of 71,412, state-of-the-art security technology, and a higher level of sustainability than any comparable building of its size, this stadium is already a landmark for Brasília — a UNESCO World Heritage city that is home to 2.6 million people.

New standards for sustainability were set even before construction began. For instance, chunks of concrete left over from demolition activities were recycled as part of the stadium's foundation. And during construction, grandstands from the old stadium were integrated into the new building. The playing field was lowered by a full four meters in order to guarantee that spectators would have a better view not only during the World Cup and the Olympic Games — the latter will take place in 2016 — but also later, when the facility will be used as a venue for concerts and other events. Guilherme Mendonça, who is responsible for Siemens Infrastructure Solutions in Latin America, considers the new stadium an asset for the city of Brasília: "One of the big advantages this stadium has over others is the variety of uses it is suitable for, whether soccer games or concerts."

The arena's imposing roof gives the impression of being monumental and yet delicate. Supported by 288 steel columns, it seems to float above the stadium. But the truly special nature of this roof is revealed in its details. These details are what earned the Mané Garrincha stadium a LEED (Leadership in Energy and Environmental Design) Platinum sustainability certificate. It is the first sports arena worldwide to be so certified. LEED certification confirms that a building complies with the highest standards for sustainability in terms of environmental friendliness and resource conservation. For instance, over 10,000 roof-mounted photovoltaic panels arranged in a ring transform sunlight into electrical energy, collectively producing a total capacity of 2.5 megawatts. When operating at full capacity during peak periods, these cells can provide over 50 percent of the stadium's energy needs. This investment is particularly valuable in view of Brazil's new net metering law, which has made it possible for the stadium to switch between the main power grid and its own independently generated energy as needed. What's more, during normal operations it can simply feed surplus solar energy into the power grid.



Source: www.estadionacionaldebrasilia.com.br, Castro Mello arquitetura esportiva

Most of the stadium's water is provided by rain, and up to 50 percent of its power by sunlight.

The ivory-colored glass roof, which projects up to 80 meters above the grandstands, provides natural lighting for the playing field while offering shade from the hot Brazilian sun. Rain that collects on the roof is funneled through a drainage system into five large tanks that are located under the stadium. The tanks have a total capacity of almost seven million liters. Once collected, the water is filtered on site and then used for the facility's sanitation systems as well as for watering the grass. These steps have made it possible for the stadium to cover over 80 percent of its water needs. Siemens building automation technology ensures that the stadium's renewable energy systems and its water management system make the most efficient use of resources possible.

The roof of the Estadio Nacional Mané Garrincha is also extraordinary in terms of its surface coating, which is composed of a photocatalytic membrane that collects air pollu-

tants. Titanium dioxide-coated surfaces ensure that contaminants such as nitrogen oxides, unpleasant odors, and biofilms (algae, fungi, bacteria) are degraded into harmless compounds by oxygen and water. Organic materials on the surfaces are decomposed through exposure to the sun's rays. The result is reduced air pollution. Rain washes the surfaces clean, making the use of environmentally harmful chemicals to remove contaminants unnecessary. The facade is open between the roof and the stands, air within the stadium circulates naturally, thus ensuring that heat, which accumulates in the walls, is drawn upward. In a region with a tropical climate, it's an innovative idea. This approach eliminates the need for extensive air conditioning and ventilation systems.

In order to ensure the safety of fans, employees, and players, the stadium's operators rely on the latest security technology. A surveillance system from Siemens uses highly advanced camera technology, including image processing algorithms that identify potential dangers in the stands. This helps security guards to react more quickly to threats and to take appropriate action. The stadium's security and efficiency have also benefited from a range of systems installed by Siemens, including some 6,000 smoke and fire detectors, a cutting-edge IT and sound system, and 158 turnstiles for access control.

Flexible Access. Indeed, thanks to a database that is able to recognize all of the ticket systems on the market — 1D and 2D bar codes, Mifare, and smartcards — the facility's access control system offers the highest level of security and flexibility. For employees, password-protected access means that they can enter authorized areas without the need to carry a key. Finally, all of the technical systems are connected to a single control center and can be operated from a single display.

Vincente de Castro Mello, architect and project leader of the Estadio Nacional Mané Garrincha, sees the stadium as a model for other sports facilities. In fact, he suggests that in the future perhaps even more could be done. Why not build sports facilities that could serve as renewable energy power plants for surrounding neighborhoods? But that's the future. For now, Castro Mello is clearly satisfied that the stadium is both environmentally sustainable and economical. "The problems of climate change, high energy costs, and water scarcity are everywhere," he says. "We have taken all of these issues into consideration in the construction of this stadium." ■ *Maximilian Marquardt*

From pipe-laying ships to research vessels, many marine activities benefit from quiet, energy-efficient, and adaptable diesel-electric drives from Siemens.

Silence at Sea

Norway has a long tradition of shipbuilding. Engineers there are developing drive concepts for ship propulsion that are energy efficient and nearly as silent as those of submarines. Hybrid drives play a key role in this effort.

The Vikings loved their ships. These seafarers sailed and rowed their "dragon boats" all the way to North America. More than a thousand years later, one of their homelands, Norway, is still one of the world's leading shipbuilders. In fact, each year the country's shipbuilding industry earns around eight billion euros in revenue. Siemens is among the many companies that count on the skills of Scandinavian ship designers. One of them is Odd Moen. From Trondheim, where he works in sales for Siemens Marine & Shipbuilding, Moen oversees projects around the world. But his goal is always the same: to optimally adapt drive system to anything afloat.

Moen's department has already outfitted more than 200 ships with complete powertrains, thus doing much for maritime energy efficiency in the process. "We use diesel-electric propulsion systems for many ships," he says. "In these installations, the ships' propellers, or 'screws,' are turned by inverter-fed electric motors that get their energy from diesel-powered generators. This arrangement gives us much finer control of the screws, which results in fuel savings."

Many ships must either be able to maneuver with precision on the open seas or, alternately, maintain fixed positions, for example to drill or service installations on the ocean floor. In such situations, the drive usually only needs to deliver minimal power that turns the screws slightly in order to maintain the ship's position. Compared to faster power-transfer systems, the output of the engine in a purely diesel-powered system fluctuates greatly. As a result, the engine often does not operate at optimal efficiency. In addition, such ships have not made efficient use of the energy content of their fuel.

"In order to maintain a vessel's position at sea or to move at very slow speeds, the amount of propulsion needed is sometimes so minimal that it need not be more than the power to adjust the pitch of the propeller blades," explains Moen. "The propeller turns at a constant speed. As a result, the diesel engine also does so." Today, the frequency converter, by way of the electric motor, controls the propeller rotation speed directly. As a result, the propeller can turn much more slowly.

This configuration saves fuel because electric motors operate at high efficiency even at low speeds. A frequency converter controls the speed of the electric motors and propellers. Depending on how much thrust is required, the converter adjusts the frequency and amplitude of the alternating current from the diesel generator.

Depending on the type of ship, a diesel-electric propulsion system consists of four to six diesel generators. The ship's power demand determines how many of the generators are running. As a result, since they produce only the energy that is needed and are not directly coupled to the speed of the screws, diesel engines can operate at a very high level of efficiency. In ships where the load on the propulsion system changes frequently, the savings provided by this type of hybrid system more than compensate for the loss in efficiency due to converting the mechanical energy produced by the diesel engine into electrical energy. Compared to purely diesel-powered vessels, diesel-electric ships are quieter and use up to a third less fuel. Siemens has been using this technology since 1996. The *Skandi Marstein,* a supply boat for drilling platforms, was the first vessel with a diesel-electric drive in the North Sea. "That ship was a milestone for us," says Moen. On a three-day cruise, the *Skandi Marstein* used 35 percent less energy than a diesel vessel."

Pipeline Ships. Over the years, the diesel-electric principle has changed very little. However, the use of state-of-the-art components can still improve vessel efficiency. "The complexity of a project grows as the complexity of the individual components increases," explains Moen. Starting in 2016, exactly 20 years after the *Skandi Marstein* entered service, four pipeline-laying ships with diesel-electric drive technology will be launched — the largest contract in the history of Siemens Marine & Shipbuilding in Norway. "Although the *Skandi Marstein* was advanced for its time, it is actually no more than a floating truck," observes Moen. "It delivers supplies to a drilling platform and hauls away trash. But the new pipeline ships will have to operate under much more extreme conditions, hold their exact positions in deep water, and provide plenty of energy for welding, insulating, and laying pipelines." Up to 150 meters long and with enough buoyancy to carry a 650-ton pipe-laying tower, these ships are true leviathans — and they will have to maintain their positions even in harsh conditions. Each ship is equipped with six diesel engines, which provide the electrical supply for six propellers and the pipe-laying equipment. At any given time, only those diesel engines that are actually needed will be in operation. This strategy, together with the use of electric motors, will reduce fuel use and maintenance costs. Looking ahead, Moen sees a lot of potential for drives similar to those found in hybrid cars that use batteries to compensate for fluctuations in propulsion power. An example of this type of system is found in the hybrid-powered *Prinsesse Benedikte,* a ferry that connects Denmark and Germany. The vessel carries more than 300 cars and 1,000 passengers per trip. The 140-meter ship has a propulsion system similar to those in the pipeline ships. Generators powered by 17,440-kilowatt diesel engines produce the electricity that drives its electric motors with the help of frequency converters. In this case, however, Siemens integrated a battery with a storage capacity of around 2,900 kilowatt-hours into the drive system. The battery compensates for the motors' varying energy requirements depending on whether the ferry is moving or docked. As a result, the diesel engines can operate more evenly and at close to their optimal efficiency. The addition of a battery has allowed the ferry to save up to 15 percent on fuel, while helping to reduce wear on the diesel engines.

For short trips with long port calls, all-electric propulsion systems are feasible. Here, power is drawn from batteries, which can be recharged while the ferry is docked. The first purely electric ferry is set to enter service in 2015, transporting cars and people across a Norwegian fjord (see *Pictures of the Future*, Spring 2013, p. 110).

Diesel-electric ships use a third less fuel than ships equipped with purely diesel-powered drives.

Many other kinds of vessels have also been equipped with Siemens drive technology. For instance, research ships benefit because they require particularly quiet drives (almost as quiet as those used for submarines). And in the case of fishing boats, ship designers at Siemens have been able to increase onboard storage space by 40 percent. Since the diesel engines no longer have to be directly connected to the propellers, the drive system can be installed with more flexibility. As a result, available space can be used more effectively.

"We always find the right solution for each ship," says Moen. Nevertheless, despite the vast range of design possibilities, he admits that a Viking ship would present a formidable challenge. Of course, it would be efficient and save fuel, but who wants to row when there's no wind? ■ *Andreas Wenleder*

An electric arc furnace. Almost every building and vehicle needs steel. Worldwide, over 1.5 billion metric tons are produced per year.

Tapping the Fires of Efficiency

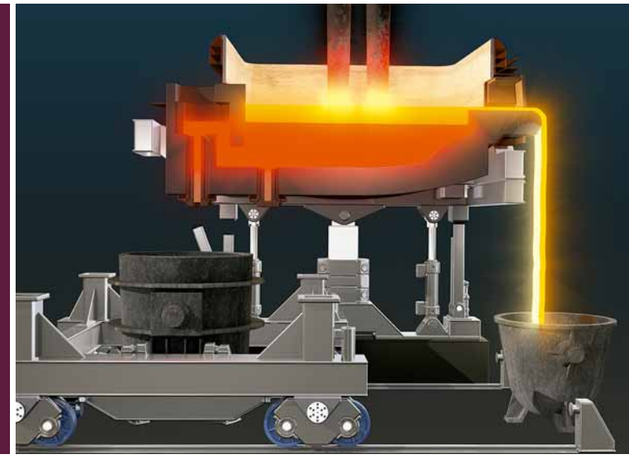
Siemens technologies are helping to reduce energy demand in steel mills, whether in scrap recycling or classic blast-furnace processes. The result: reduced resource demand and emissions and a healthy reduction in operating costs.

A storm is raging in a powerful electric arc furnace. Every few seconds, there are deafening blasts and hissing noises. A red-hot mixture bubbles in the furnace like lava in a volcano. The infernally hot blaze is fed by high voltage from graphite electrodes as thick as manhole covers, and it melts scrap into new steel at temperatures over 1,540 degrees Celsius. An electric furnace of this kind often devours more power than a small town. But traditional steel production, which uses iron ores in conventional blast furnaces, is also an energy-intensive business. Operating at temperatures over 1,400 degrees Celsius, such furnaces, which can easily be as tall as a high-rise building, use iron ore, coal, coke, and aggregates to produce pig iron, which is then heated and refined into steel.

It is thus not surprising that, in addition to essential materials for ships, cars, railways and bridges, the steel industry also produces a large amount of carbon dioxide because of its demand for energy and coal. "Steel mills account for 6.7 percent of global carbon dioxide emissions," says Dr. Alexander Fleischanderl, head of Technology and Innovation Management for Steelmaking and ECO Solutions at Siemens VAI Metals Technologies in Linz, Austria. He doesn't want to consider steel mills enemies of the environment, however, because products made of steel are also indispensable tools for saving energy. They are essential parts of wind turbines, solar energy systems, and highly efficient gas turbines, for example. Furthermore, in recent decades steel manufacturers have been able to reduce energy inputs and thus CO_2 emissions dramatically. "Fifty years ago, about 30 gigajoules were used for every metric ton of finished product in Europe; in 1990 it was 24, and today it's less than 18 gigajoules per metric ton of finished product," says Fleischanderl. "Today a typical integrated steel mill with a production capacity of five million metric tons of end product emits approximately eight million metric tons of carbon dioxide, or 37 percent less than in 1960."

But there's room for improvement, primarily because waste heat remains largely unused. "Almost a third of the energy used in steelmaking is lost in the form of waste gas from electric arc furnaces, which has a temperature of approximately 1,400 degrees Celsius," says Dr. Markus Dorndorf, head of research and development for Siemens' Electric Steel Production unit. But if this heat is used to drive a steam turbine, ten percent of the electricity input can be recovered. With this in mind, Stahlwerk Thüringer GmbH, a producer of electric steel about 60 kilometers south of Erfurt, tapped Siemens, which designed and supplied an energy recovery system based on the use of molten salt storage tanks between the heat source and the steam turbine, thus ensuring a steady flow of energy.

Carbon dioxide emissions can also be sharply reduced if scrap is preheated with process waste gases — a technique used by the new Simetal EAF Quantum arc furnace from Siemens. The first high-performance furnace of this type is currently being built in Mexico for steel producer TYASA and is scheduled to enter service in the first half of 2014. The EAF Quantum arc furnace uses 20 percent less power than conventional solutions. But it also offers a range of other benefits, including higher process speed, longer life for the melting electrodes, and more rapid amortization than conventional electric arc furnaces.



Left: A new electric arc furnace from Siemens uses process waste gases to heat up scrap before melting. This reduces energy demand by over 20 percent.

Right: Huge graphite electrodes heat scrap to 1,540 degrees Celsius, converting it into new, high-quality steel.

Waste Gas As a Resource. Greenhouse gas emissions can also be cut substantially when pig iron is produced from iron ore in the blast furnace process. The potential for reduction starts with sintering. In this process, iron ore, fuels such as coke or coal, and flux materials are mixed, placed on a grate, and heated from above. As a result, they are baked together. "In a typical plant, this produces more than a million cubic meters of waste gas per hour, and the gas contains incompletely combusted carbon monoxide, among other things," says Fleischanderl. But with Siemens' Selective Waste Gas Recirculation (SWGR) technology, up to 50 percent of the waste gas can be fed back into the sintering process. The carbon monoxide can then function as fuel once more, thus reducing coke demand and carbon dioxide emissions by approximately ten percent. And the lower volume of waste gas results in lower costs for waste gas purification. For a few years now, SWGR technology has been delivering good results at the sintering plant of steel producer voestalpine in Linz, Austria, among other places. Furthermore, together with Siemens' MEROS waste gas purification technology, which earned Fleischanderl the Siemens "Inventor of the Year Award 2013," the Linz plant also removes up to 99 percent of the pollutants (including sulfur oxides, nitrogen oxides, heavy metals, and organic compounds such as dioxins) or converts them into harmless substances. In the MEROS system calcium hydroxide and other materials, for example, are used to convert sulfur dioxide to gypsum, and heavy metals and dioxins remain trapped in dry sorbents such as HOK or activated coke. The adsorbants needed for this are blown into the waste gas stream at high speed. Then the mixture of additives and waste gas is sprayed with water to cool it to about 90 degrees Celsius. "That accelerates the desired chemical reactions," says Fleischanderl. The particulate matter is then separated, and since it still contains active additives, it can be recirculated into the waste gas stream multiple times. Siemens has already built three MEROS plants in Austria and China, and there are orders for one in Turkey and four in Italy.

MEROS purification technology removes 99 percent of pollutants from steel mill waste gases.

The following step, in which iron sinter and flux materials are fused into pig iron in a blast furnace to produce steel, also produces waste gases, and it would be a shame to just flare them off. After all, these combustible process gases contain large amounts of carbon monoxide. These days, they are usually delivered to gas-fired power plants, where they are converted to electricity at an efficiency rate of less than 40 percent. However, the utilization rate of these waste gases can be further increased. "With biofermentation, bacteria can be used to convert carbon monoxide to ethanol and other valuable industrial chemicals," says Fleischanderl. With this in mind, Siemens is working with LanzaTech, an American gas fermentation company. Bioethanol production from com-

Left: Steel scrap is melted in special furnaces. Top: ESP-based sheet metal production is particularly efficient. Bottom: Steel expert and inventor Dr. Alexander Fleischanderl.

bustible process gases has an efficiency rate of over 60 percent and doesn't compete with the cultivation of crops. A demonstration system is already up and running in China.

Slag to Cement. Even slag, a by-product of blast furnace production, has plenty of potential that can still be tapped. Worldwide, almost 400 million metric tons of it are generated every year. In conventional processes, when it is sizzling at approximately 1500-degree-Celsius, slag is separated and dumped into a tank of cold water. This results in the formation of a granular material that goes primarily into cement production. But with a new Siemens process the slag can be granulated while dry, making it possible to capture large amounts of its heat. "In this dry granulation process, the slag is cooled with air. It is put on a rotary plate and broken apart and granulated through centrifugal force alone," says Fleischanderl.

Process waste gases can be reused in many ways — to generate power or as fuel, for example.

During this process, the cooling air heats up to approximately 600 degrees Celsius. If the air is then fed through a heat exchanger, its thermal energy can be used to generate steam, which can be used as a heat source directly or else converted to electricity. For every metric ton of blast-furnace slag, about 1.5 gigajoules of energy, or a bit more than 400 kilowatt-hours, can be recovered in this way. In the case of a blast furnace, that would represent an electrical generation capacity of between 10 and 30 megawatts, depending on the size of the furnace. This obviates costly processing of cooling water and .expensive cooling towers. What is more, the granulated material doesn't have to be dried. That saves another 130 kilowatt-hours of energy, at least, for every metric ton of slag. In view of these advantages, Siemens is now planning to build a demonstration system together with steel manufacturer voestalpine in Linz.

In converters — huge containers resembling soup vats — the pig iron from a blast furnace is combined with scrap, flux material, alloying agents, and oxygen and converted into the desired steel. For this process too, Siemens engineers have developed an energy-saving technology that even makes steel production more flexible. With the Jet Process, a converter can accommodate not just pig iron but also much larger quantities of scrap, and handle it more efficiently than before. In this process, coal, oxygen, and lime are introduced into the molten pig iron through bottom tuyeres (nozzles), while approximately 1,300-degree-Celsius oxygen-enriched air is fed in from above through a lance. "This process mixes everything together much better than in conventional converters, resulting in optimal conversion of coal to carbon dioxide," says Dr. Gerald Wimmer of Siemens VAI Metals Technologies in Linz, one of the developers of the process. In addition, the heat released during the conversion goes back into the molten steel bath, instead of disappearing with the waste gas.

From Furnace to Rolled Sheet. For a few years now, Siemens has had a very effective energy-saving technique on hand for processing newly smelted steel and turning it, for instance, into sheets. It is called Arvedi ESP (Endless Strip Production) and was developed by Italian steel producer Arvedi (see *Pictures of the Future*, Fall 2009, p. 64). Here, blazing hot steel strip that is cast from the converter melt is not, as is usual, cut, temporarily stored, and cooled, but instead immediately processed further. "The cast strip is allowed to pass whole and without stopping through the production line, from casting to rolling to coiling in a finished sheet," explains Sales Manager Andreas Jungbauer at Siemens in Linz. With this process, the equipment has to do far less reheating when the strip is brought to the required 1,200 degrees Celsius again for rolling. Indeed, associated energy demand can be reduced by up to 45 percent. That lowers carbon dioxide emissions by up to 39 percent, while cutting process costs by 37 percent compared with conventional plants. Furthermore, with Endless Strip Production, there is no discarded material resulting from cutting the strip. This Siemens technology, which is now in use at a steel plant in Cremona, Italy, will soon also be operational at two installations to China that are expected to enter service in 2015.

In the future, hydrogen and power generated from the wind and sun could play an important role in steelmaking.

Last but not least, automation systems can save a large amount of energy throughout the entire steel-making process. "During the previous decade, the focus was always on producing more and producing faster. Now, though, there are substantial overcapacities, and steel mill utilization levels are often only 70 or 80 percent," says Fleischanderl. Technology sold by Siemens under the brand name "Green Button" to multiple sectors of industry optimizes the energy use of industrial processes at whatever the current rate of utilization may be.

For example, pumps and fans for dust-removing equipment can be automatically throttled or switched off when they are not needed. Initial field tests have shown that such steps can reduce associated energy demand by up to 40 percent. One example, says Fleischanderl, is Precon, an automation solution that optimizes the power feed to electrostatic precipitators used for converter gas purification. "If the steel industry were to use all the currently available Siemens technologies for saving energy and raw materials and minimizing CO_2 emissions, it would be doing practically everything that makes sense economically and is physically possible," he says.

A quantum leap beyond that is possible, he believes, only by switching to renewable energies. For example, the energy demand of electric arc furnaces could be satisfied with electricity from wind or solar power plants. Furthermore, renewably-produced hydrogen could replace a large amount of the coal and coke used for pig iron production.

Like these materials, hydrogen is both a fuel and a chemical reducing agent, and it can extract oxygen from iron oxide in ore. In such a constellation, instead of carbon dioxide, the only thing coming out of the smokestacks of steel mills would be water vapor. For that, of course, there would first have to be sufficient quantities of hydrogen available. But that could be the case just a few decades from now, according to Fleischanderl. And he believes converting processes in steel mills wouldn't be a major problem. "We're already well prepared for that," he adds. ■ *Andrea Hoferichter*

World's Top 10 Steel Producers

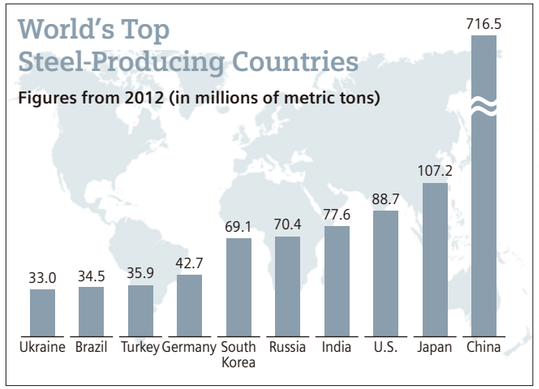
Steel output by company (millions of metric tons per year)

1	ArcelorMittal (Luxembourg)	93.6
2	Nippon Steel & Sumitomo Metal Corporation (Japan)	47.9
3	Hebei Group (China)	42.8
4	Baosteel Group (China)	42.7
5	Posco (South Korea)	39.9
6	Wuhan Group (China)	36.4
7	Shagang Group (China)	32.3
8	Shougang Group (China)	31.4
9	JFE Group (Japan)	30.4
10	Ansteel Group (China)	30.2

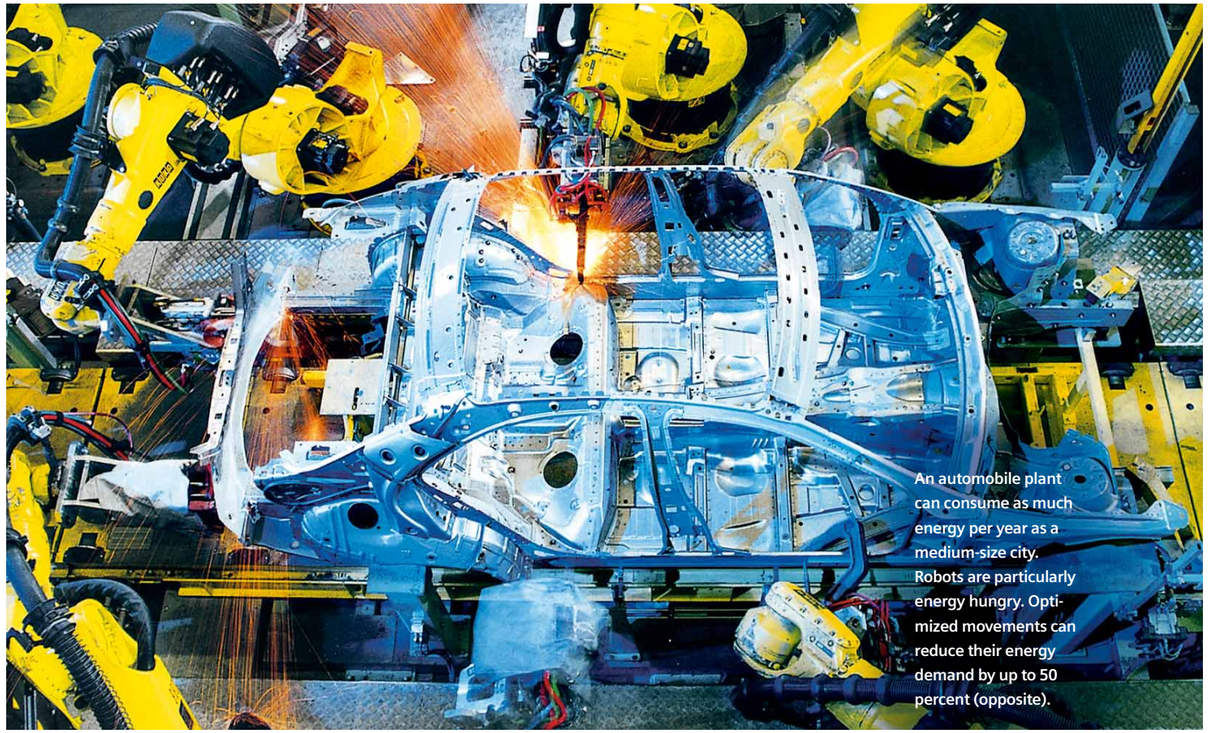
Source: World Steel Association, World Steel in Figures 2013

World's Top Steel-Producing Countries

Figures from 2012 (in millions of metric tons)



Source: World Steel Association, World Steel in Figures 2013



An automobile plant can consume as much energy per year as a medium-size city. Robots are particularly energy hungry. Optimized movements can reduce their energy demand by up to 50 percent (opposite).

Ballet of the Bots

Auto industry robots consume more than half of the total energy required to produce a vehicle body. Siemens has teamed up with Volkswagen and the Fraunhofer Society to develop movement-optimizing algorithms that substantially reduce robots' energy demand.

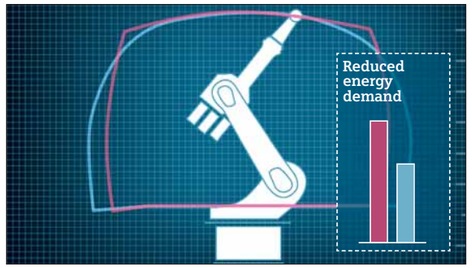
A huge robot arm effortlessly lifts a car door and installs it into a vehicle body with millimeter precision. Other arms rapidly approach, missing each other by only a few centimeters. Sparks fly as the robots weld the door's hinges to the frame. Once this task is completed, the arms withdraw as quickly as they appeared and the vehicle body rolls on to the next assembly station. Like a well-rehearsed ballet ensemble, thousands of industrial robots may work in a factory around the clock. Unlike dancers, however, robots don't need to take any breaks. On the other hand, their appetite for energy is insatiable.

An automobile plant with a daily output of 1,000 vehicles can easily consume several hundred gigawatt-hours of electricity per year — as much as a medium-size town. Around two thirds of industrial power demand is accounted for by electric motors that drive conveyor belts, machinery, and pumps, or that operate robotic joints. Yet the industrial robots that assemble vehicle bodies still have a long way to go in terms of the energy-saving potential in their control systems.

To find out what could be done about this, Volkswagen, Siemens, and the Fraunhofer Society have embarked on a three-year research project that is examining the movements of manufacturing robots. Called Innovation Alliance Green Carbody Technologies (InnoCaT), the project is designed to use efficient software solutions to optimize the production process in such a way that it consumes considerably less energy. To date, the movement paths of production-line robots have generally been programmed manually. Obstacles encountered by robots as they move around, and mistakes in setting installation heights are typical factors that drive up energy demand. However, the most energy-consuming processes are the frequent decelerations and accelerations that occur whenever a robot changes directions.

"Today, almost no industrial robot has optimized movements," says Matthias Frische, Integration Manager at Siemens Industry and head of an InnoCaT subproject. "But abrupt movements create peaks in energy consumption and mechanical stresses." In view of this, an important result of Frische's research is a simulation model that computes optimized curves without any abrupt changes in direction. What's remarkable about the model is that it does not require replacement of robots, since it merely improves their movements. "You could compare it to attending ballet class," says Frische. "After a while, you learn how to move more gracefully and efficiently even though you still have the same body."

To develop movement-optimizing algorithms, the project team put a typical automobile-industry robot into a lab and analyzed how much energy it needed to perform various tasks. The results were then translated into a simulation model. Scientists adjusted various parameters after each measurement, thus gradually determining which settings had the most energy-saving potential. "When human beings carry heavy objects, they intuitively make sure their movements are as ergonomic as possible. Similarly, the simulation model computes kinetically optimized, energy-saving movement paths for robots," explains Frische. "Such paths can be compared with the trajectory of a race car along a curve." The project team was pleasantly surprised by the lab results, which showed that the optimized paths resulted in potential energy savings of 10 to 50 percent. "By transitioning from abrupt to sweeping movements, the robots' mechanical stress is reduced, thereby reducing maintenance and downtime," adds Frische.



The team's promising lab results are being analyzed to determine if they can be transferred into real-life operations. Because the assembly stations along a production line have to fit together as seamlessly as cogwheels, the robots' redesigned movements must be as rapid as their abrupt predecessors', and cycle times must be precisely adhered to.

During the first stage of their work, the researchers manually reprogrammed the movement paths of robots used in body manufacturing. The paths were based on the ideal curves computed in the simulation. The resulting measurements showed that energy savings could be as high as 50 percent even under real-life production conditions. In a second stage in early 2014, engineers tested and improved a software module that automatically optimizes the energy demand associated with specific movements.

Programmers at first specified the positions that a robot would have to reach, such as a collection of welding spots. Within seconds, the software can compute the most energy-efficient paths between such spots. The software also ensures that robotic arms maintain a minimum distance from each other. This is no easy task, since the arms must move rapidly through complex sequences of positions. It takes the software only a few seconds to make all of the calculations. By comparison, it would take several days to optimize each robot's movement path manually. Because automobile assembly plants typically have thousands of robots, the effort required to perform this task manually would be disproportionately high. For Frische, the benefits are obvious: "Our software will for the first time allow the energy efficiency of movement paths to be optimized automatically, and thus cost-effectively," he says.

An associated software module for Siemens' Tecnomatix production planning software may be launched on the market later this year. "Manufacturing companies could practically reduce their energy demand at the push of a button and also contribute to environmental protection," says Frische. "Our software lets programmers choreograph the resource-conserving interplay of robots."

■ *Stefan Schröder*

Robots and Machine Tools: Merging of the Minds

Manufacturing is becoming increasingly automated. As a result, producers are finding new ways to use resources more efficiently while improving the flexibility of their processes. An important precondition for this development is the precisely coordinated operation of production machinery with a focus on how robots and machine tools interact. That's why Siemens and KUKA, one of the world's leading suppliers in the robotics and machine production sector, are working together to merge the control systems of robots and machine tools.

State-of-the-art machine tools are a major investment for a company. It therefore makes sense to maximize their utilization and efficiency. In the past, industrial robots that insert workpieces into machines and take them out again after they have been processed were programmed by means of their own control units. Now, however, such robots can be directly programmed through a machine tool's user interface. This makes it possible to better coordinate machines' processing steps, while substantially reducing the effort needed to program associated robots.

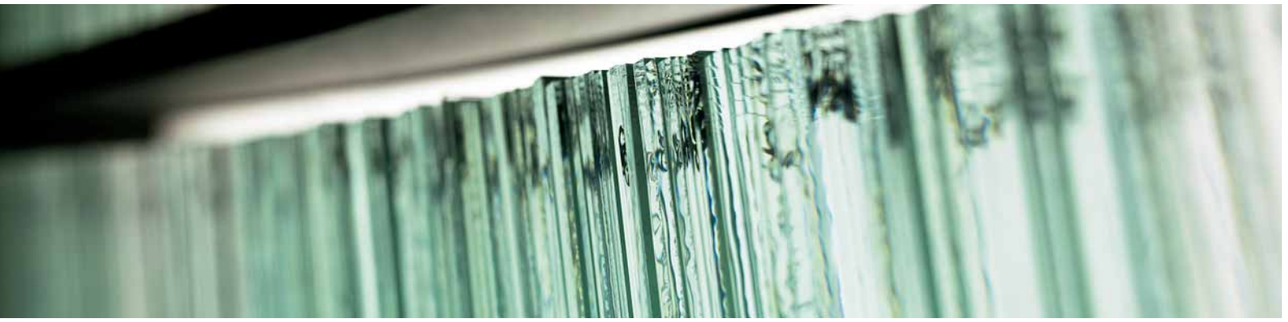
Another aim is to further improve the interplay between robots and machine tools in the processing of workpieces. In the future, robots will be required to take on simple tasks such as grinding and milling, particularly when working on new materials. Machine tools will then be used specifically for production steps that require a great deal of force or extremely high precision; this is expected to improve machine tool utilization.

Because of their wide reach and flexible axes of motion, robots can also work on parts that are complex or very large. For example, they could replace expensive specially-designed equipment for processing rotor blades or wing parts. In these cases as well, systems would be controlled by means of a shared user interface. All of this will improve coordination among machines throughout their entire lifecycles — from design to the manufacturing simulation phase, and through to the engineering and workshop stages.

State-of-the-art energy management, heat recovery, and automation technologies of the kind used at f | glass cut energy demand by about one fifth.

The Energy Efficiency Bonus

The ability to use all forms of energy efficiently is becoming a crucial competitive advantage for companies and entire economies. The latest automation control and predictive load management systems are not only playing a key role in this area, but turn out to pay for themselves rapidly.



At Gardena Manufacturing near the ancient town of Ulm in southern Germany, work proceeds at a brisk pace, and in a high-pressure environment — quite literally. Each year, the site's 93 injection molding machines turn 9,400 metric tons of plastic into 500 million parts, such as handles for pruning shears and push lawn mowers. Work proceeds seven days per week, from Monday to Friday at full capacity in three shifts, while weekends are a bit slower with fewer machines and workers on duty.

It is a clear pattern, and power demand at the plant follows the same routine. On an average workday, Gardena Manufacturing, a company in the Husqvarna Group, uses an average of between 2 and 2.3 megawatts (MW). On Saturdays and Sundays energy demand drops to one or two megawatts, depending on the workload.

This regularly repeated pattern is something the power company has adjusted to. It knows how demand will change over the course of the week and can plan its output accordingly. This pattern is reflected in its supply contract guidelines with Gardena Manufacturing. On the one hand, the company must pay for the electrical energy it uses, just like any private household. On the other hand, the power company guarantees that Gardena can always pull up to 2.68 megawatts of power.

But exceeding that amount on even a single occasion would be expensive for the plant. "The power company determines our average power use in fifteen minute intervals," explains Jürgen Röck, who shares responsibility for automation and load management at Gardena Manufacturing. "If we are over the contractually agreed maximum during even a single interval, that costs us a lot of money, because then the power company raises the guaranteed maximum value for the rest of the year, and of course we have to pay for that."

A few years ago it happened. When Gardena's machines were started up after Easter, power demand suddenly rose to 3.2 megawatts for a short period, because the machines required a particularly large amount of power when starting up in unison. Gardena wanted to prevent that from happening again. As a result, the company decided to use the latest load management technology. In the spring of 2010, engineers installed nine Siemens Sentron PAC 3200 monitoring devices at the plant's transformers. The devices measure current, voltage, and power. Their measurements are fed into a Simatic S7-400 controller that produces a power demand forecast for the current 15-minute interval. The goal here is clear: Average power demand should never exceed the limit of 2.68 megawatts.

Röck, an electrical technician, can look at the plant's current status at any time. All he has to do is to click the Siemens Simatic WinCC Powerrate app on his desktop computer. "A green area shows me how much electrical energy we've already used," he says. "An orange-colored line shows the forecast for the remainder of the 15-minute interval. As a result, we see immediately whether we're in danger of going over the maximum."

But if the plant gets too close to its limit, the system responds automatically. The controller gradually scales back power use until things are back to the normal range. In 200 kilowatt stages, it reduces the power of the systems that extract heat from the process water that cools off the molds in the injection molding machines. Here, a short-term temperature increase is not a problem. Similarly, the drier for the plastic pellets can also respond flexibly to load management needs. Its power can be reduced in four stages by 28 kilowatts each time.

The control system has proven to be remarkably effective. Since it was installed, power demand has never exceeded the stipulated maximum. "Since we already use a great deal of Siemens equipment, the installation of the load management system didn't cost very much. For example, we were able to use the existing S7 communication system for data transfer among the Siemens controllers," says Röck. "Thanks to its reduction in peak loads, the load management system will pay for itself within a year."

And Gardena Manufacturing plans to further expand its energy monitoring. In the near future, for instance, Röck will be able to use Win CC to keep track of how the compressed-air and heating systems are working. Although he won't be able to influence power demand this way, the readings will provide him with valuable clues regarding possible leaks in pipes or pumps that could be draining energy from the plant.

Many companies already have efficient and energy-saving production processes — but there's lots of untapped potential.

Avoiding Peaks. Power demand management is a hot topic in industry because load peaks in production can be astronomically expensive. But in the future, companies will not only have the capacity to avoid outliers — demand peaks — they will also be able to use intelligent load management to draw power at precisely the times when there is an oversupply in the grid. "If you shift your power-intensive processes to periods when there is an abundant power supply and a low price, you can offer ancillary services that stabilize the grid," says Dr. Frank Büchner, head of German operations at the Siemens Energy Sector. "Companies that can do this also benefit from lower energy prices and become less reliant on the current state of supplies — and they can make an important contribution to the success of the transition to a sustainable energy policy," he adds.

In addition to load management, companies are increasingly investing in energy efficiency measures, and their efforts are paying off. The German Federal Statistical Office calculates that energy productivity in Germany rose by 46 percent between 1990 and 2012. As a result, the average company operating in Germany now uses substantially less primary energy to manufacture products or supply services. The goal of the German federal government is to achieve a rate of energy productivity double that of 1990 by 2020.

Monitoring systems play an important role in attaining this goal, because they reveal areas where energy is being wasted. Crucial factors are the use of efficient components and systems to recycle unused energy, such as waste heat. By increasing efficiency in these ways, companies not only help reduce greenhouse gases and protect the environment. They may also help ensure their own well-being, since in times of increasing energy prices, maximum energy efficiency can quickly decide the fate of an enterprise in the global marketplace.

This is particularly true in Germany, a country in the process of transitioning to a more sustainable energy supply. "German companies already pay up to 24 percent more for power than the EU average, and up to three times more than companies in the U.S.," says Rudolf Martin Siegers, CEO of Siemens Deutschland. "Investments in energy efficiency are thus anything but extra costs — on the contrary, they can make it possible for a company to survive."

Nevertheless, there is a great deal of untapped potential in this area. According to the Energy Efficiency Index of German Industry, which was published for the first time in December 2013 by the Institute for Energy Efficiency in Production (EEP) at the University of Stuttgart, the Federation of German Industries (BDI), the German Energy Agency (dena), and TÜV Rheinland — companies still invest too little in energy efficiency, despite the fact that these investments are highly profitable.

The researchers surveyed 80 companies in industries such as machine production, metal production, and plastics and glass manufacturing. "About two thirds intend to allocate less than five percent of their investments to the field of energy efficiency," re-

Investments in energy efficiency are paying off within just a few years at dozens of Siemens facilities, such as a medical equipment center (right).

ports Robert Kasprowicz of EEP. "And only nine percent plan to allocate more than 20 percent of their investment resources here."

The reason for this reluctance is that many companies require a 100 percent return on investments in only 30 to 36 months, and they are not prepared to commit capital for longer periods, although an examination of the total cost of ownership shows that such investments are worthwhile in most cases. Kasprowicz sums up the results of the study by saying that "everyone talks about improving energy efficiency, but not enough is actually being invested."

Industrial energy demand could be cut by twelve percent by exploiting waste heat.

Following their first study in late 2013, the participating institutes intend to publish a new survey every six months and use the results to calculate an energy efficiency index that describes current conditions and trends in the realm of energy efficiency and is based on the business climate index calculated by the Ifo Institute for Economic Research.

Sylvia Wahren of the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA) sees plenty of room for improvement. An efficiency expert who advises companies on specific projects, Wahren says that, "There's a lot of talk about energy efficiency, but the message hasn't completely gotten through at most companies. For instance, the recovery of waste heat over 140 degrees Celsius would result in a huge quantity — 320 petajoules — of heat that could be put to use. That represents approximately twelve percent of industrial energy use in Germany." As she sees it, many companies adopt inexpensive steps that show quick results, such as efficient lighting systems, but hesitate to implement steam turbines or Organic Rankine cycle technology to generate electrical power from waste heat.

The latter is also an option, however, as illustrated by the company f | glass GmbH in Osterweddingen, Germany. Each day, up to 700 metric tons of special-purpose glass leave the company's production plant near Magdeburg, some of it destined for the solar industry. The plant has one of the world's most modern production sites for glass — and one of the most energy-efficient. With its fully automatic production system, state-of-the-art energy management, and intelligent heat recovery, the plant's glass production consumes approximately 20 percent less energy than that of similar companies.

Efficiency steps have cut energy costs by €270,000 per year at Siemens' turbine plant in Berlin.

To achieve this level of efficiency, more than 3,000 measuring points along the plant's roughly 700-meter-long production line supply data to a SIMATIC PCS 7 process control system, which ensures uninterrupted operation around the clock, 365 days per year. Energy efficiency technology at the plant includes a Siemens-made steam turbine with a maximum output of 3.2 MW, which converts a large part of the 500-degree (Celsius) waste heat from the melting furnaces into electrical energy. The turbine alone generates approximately one fourth of the power for the plant's glass production.

Key Factors for Competitiveness. The plant's process control system also ensures optimal energy management. It reduces kilowatt-hours to a minimum thanks in part to energy-efficient, frequency-controlled drives supplied by Siemens. Energy efficiency and its associated cost savings are thus one factor that helps f | glass survive in the global marketplace. Solutions of this kind can be particularly beneficial to the glass industry. Like cement-making, basic chemicals production, and metal manufacturing, glass production is one of the energy-intensive industries which, collectively, are responsible for approximately twelve percent of final energy demand in Germany.

EEP experts estimate that these industries could reduce their power demand by up to 14 percent by 2035 if they were to implement state-of-the-art process engineering. Their survey indicates that plastics and glass producers are prepared to do so. Companies in these fields are planning to increase investments in better energy efficiency. "Energy efficiency is playing an increasingly important role for these companies," observes Siegers. "They have recognized that energy and resource efficiency are key factors for their competitiveness."

Buildings that house production facilities can also make a contribution to efficiency, as Siemens is demonstrating at its manufacturing sites. In 2005, the company launched its Energy Efficiency Program, which consists of five phases — it begins with the Energy Health Check, followed by an analysis of energy use and potential, and ends with the implementation and monitoring of the improvements that have been put in place. "These range from optimized energy procurement to better infrastructure, more efficient production operations, and changes in the behavior of plant workers," says Peter Marburger, who oversees the project at Siemens Building Technologies. "So far, we've conducted Energy Health Checks at about 100 locations, and we've already implemented measures for better energy efficiency in 26 plants. This was one reason why Siemens was able to reach its own target of reducing its CO_2 emissions by 20 percent between 2006 and 2011."

Four-Year Return on Investment. Siemens' railway technology plant in Krefeld, Germany offers a good example of an energy efficiency program that is paying off. The plant has cut its carbon dioxide emissions by 2,300 metric tons per year — and now saves almost €700,000 in annual energy costs after a one-time investment of approximately €4 million. The most important steps taken were the installation of a gas-fired combined-heat-and-power (CHP) plant, a new ventilation system with heat recovery, and an energy monitoring system that documents the facility's current energy use and thus provides a means of measuring the performance of energy-efficiency projects. These measures have reduced energy costs by 15 percent and CO_2 emissions by 20 percent.

Siemens has had similar experiences at other locations. At its Berlin gas turbine plant, for instance, energy costs were reduce by €270,000 and CO_2 emissions were reduced by approximately 1,100 metric tons per year. In the Bavarian town of Kemnath, energy-efficiency measures have helped a Siemens medical equipment plant save over €500,000 per year and obviate some 2,700 metric tons of CO_2 emissions, an approximately 25 percent reduction that goes far beyond Siemens' own initial target. At most such locations, energy-saving investments paid for themselves after about four years. "We're at the threshold of a paradigm shift," sums up Marburger. "In the past, we paid for sustainability — now sustainability pays for itself."

Christian Buck

In Brief

Energy efficiency is the order of the day. According to the International Energy Agency, global energy demand is expected to increase by one third by 2035. Efficient use of energy resources not only helps to mitigate climate change but is also a prerequisite for ensuring the future competitiveness of countries and companies. (p. 12, 20)

A future holder of three world records is being built in Düsseldorf. The Lausward combined cycle power plant will enter service in 2016. The plant is designed to have an electrical output capacity of 595 megawatts (MW), achieve an electrical efficiency of over 61 percent, and feed 300 MW to the district heating network — all of which are records (p. 16)

Wind and solar power are literally transforming Germany's energy market. In the future, not only will energy demand fluctuate, but also energy supply. In order to better manage these fluctuations, and thus optimize the energy market, Siemens researchers have developed forecasting software based on neural networks. With this software, power generation and demand can be predicted with greater accuracy. (p. 18)

Researchers involved in the Combined Power Plant joint project have found that power grids can be operated stably even with 100 percent regenerative electricity. The prerequisite is that each generating facility must have an intelligent control system that can respond in real time. (p. 22)

The "Ecogrid" pilot project is testing a smart power grid on Bornholm, a Danish island in the Baltic Sea. The project is examining ways to adjust power demand to match availability — for example, through automated control of heating systems and boilers. (p. 26)

In Norway, Siemens researchers are developing drive concepts for energy-saving ship propulsion. Hybrid-electric drivetrains play an important role in this effort. (p. 26)

The cost of energy is going up. It's also increasingly a factor influencing the competitiveness of industrial facilities. Efficient technologies reduce demand, and predictive load management helps consumers avoid high electric bills. (p. 40)

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LINKS:

Combined Power Plant research project:
http://www.youtube.com/watch?v=7IZd-Wpp26-g
EU project Ecogrid on Bornholm:
www.eu-ecogrid.net
Green Carbody Technologies project:
www.greencarbody.de
Mané Garrincha stadium, Brazil:
www.estadionacionaldebrasilia.com.br

A single bite from an *Anopheles* mosquito can transfer the *Plasmodium* parasite to a victim, thus causing malaria.

Clues in the Blood

Malaria is one of the most devastating tropical diseases, yet many cases of this infection are not diagnosed until it is too late. In the near future, the diagnostic process could be automated. Siemens researchers are developing a highly sensitive blood analysis system.

An epidemic that destroys dreams is raging in southern Africa. Malaria, perhaps the most devastating tropical disease, tears apart thousands of families every year in Africa, Southeast Asia, the Eastern Mediterranean, and South America. It also causes direct and indirect costs of billions of dollars per year.

Nonetheless, relatively little international attention is being paid to this illness. "Malaria is a forgotten disease," says Dr. David Sullivan, an infection researcher at the Johns Hopkins Bloomberg School of Public Health in Baltimore. The figures are devastating. According to estimates made by the World Health Organization (WHO), around 200 million people developed malaria in 2012. More than 600,000 died — most of them children under the age of five in sub-Saharan Africa.

Diagnosing malaria is a huge problem. "We diagnose only about ten percent of the cases worldwide," says Sullivan. That's because the symptoms of malaria are non-specific. High fever, chills, headache, and a general feeling of weakness can indicate a large variety of illnesses. In tropical countries, on the other hand, almost every case of fever is treated with malaria medications, even if it's unclear whether it is really an infection due to the *Plasmodium* parasite.

In industrialized Western countries such as Germany and the U.S., where around 1,000 cases of malaria occur every year, physicians do not always think of tropical fever when a patient comes to them with these symptoms. "By the time this illness is diagnosed, it may already be too late," says Barbara Kavsek, who heads the Biosensors group at Siemens Corporate Technology in Vienna. Even in the U.S., there are a number of deaths every year because attending physicians do not recognize malaria in time.

The gold standard of malaria diagnosis is still a microscopic examination of the patient's blood. For this purpose, a thick blood smear is placed on a slide, dried, stained, and then examined under a microscope — a procedure that requires about an hour. The blood cells burst during the staining process, which makes the single-celled parasite become directly visible. In order to determine the type of parasite — the three most common variants of malaria are caused by different types of the single-celled parasite — a thin film of blood must subsequently be examined under a microscope. Parasites that have just penetrated red blood cells surround themselves with a small bubble that looks like a signet ring. The problem with this diagnostic method, however, is that the quality of the diagnosis depends to a very great extent on how much experience the laboratory staff has had with this disease. Even in countries where malaria is rampant, the accuracy rate of the diagnoses varies widely.

Automating Parasite Detection. One alternative is the use of dip-and-react tests, which function similarly to pregnancy tests. "However, they are not one hundred percent reliable," says Dr. Hinrich Sudeck, Head of the German army's Tropical Medicine Department at the Bernhard Nocht Institute in Hamburg. As a result, many physicians would like blood samples to be routinely tested for malaria in laboratory examinations — generating a kind of malaria alarm. "A procedure of this kind would represent tremendous progress," says Sudeck.

Siemens researchers are developing a routine test for malaria. The test can be used, for example, in the ADVIA 2120 (below right), which can automatically analyze 120 blood samples per hour.

And that's exactly what researchers at Siemens' Healthcare Sector and Corporate Technology are working on. The team in Vienna and Graz, which is led by Kavsek, a mathematician, is working to make Siemens' ADVIA 2120 hematology system fit for malaria diagnostics. This laboratory instrument, which is about the size of a washing machine, can analyze 120 blood samples per hour completely automatically. It is used in many hospitals all over the world. Ampoules of blood are placed in the system in a process similar to an assembly line. Inside the device, every blood sample is processed and analyzed — reagents are added and the sample is mixed, gently shaken, and illuminated by laser beams.

The result that is delivered by ADVIA is a hemogram. Depending on the settings that are chosen, a hemogram consists of 300 to 500 parameters. For example, ADVIA counts red and white blood cells and the smaller blood platelets, determines their size and shape, and measures the Hb value — that is, the proportion of hemoglobin, the pigment that gives blood its red color. The data are saved in a laboratory information system and forwarded to the attending physician. On the basis of a hemogram, a physician can recognize diseases of the blood and the blood-generating organs such as hereditary diseases, deficiency symptoms, poisoning, bacterial infections and leukemia.

Around 200 million people developed malaria in 2012. More than 600,000, most of them children, died.

Rapid Proliferation. Malaria too is a blood disease. The *Plasmodium* pathogen penetrates the human body through a mosquito bite. It initially settles in the liver for several days, multiplies, and subsequently invades red blood cells. There this single-celled organism feeds on sugar and hemoglobin and continues to multiply. Ultimately, blood cells begin to burst, and this triggers the dreaded attacks of fever. *Plasmodium* parasites disperse in the blood plasma and penetrate new cells.

A malaria infection leaves traces in hemogram, leading, for example, to reduced numbers of blood platelets. However, this characteristic also applies to other diseases. As a result, it is not possible to definitely di-

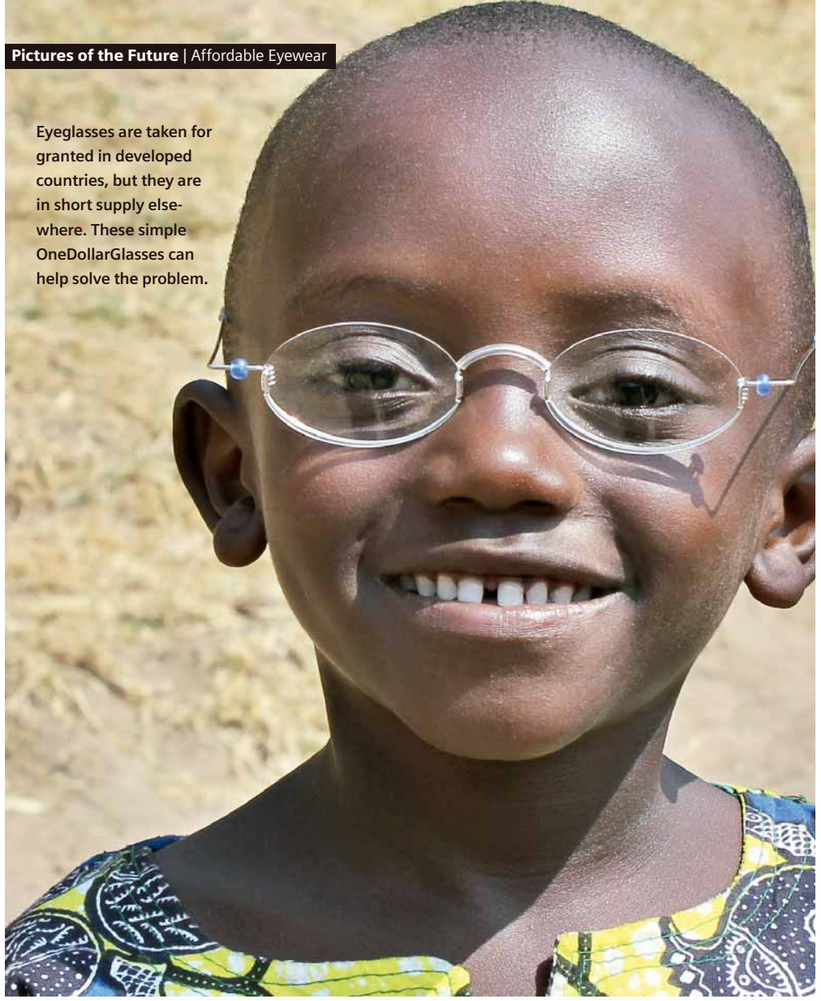
agnose malaria from this or other individual values. An additional challenge is that the various malaria pathogens, whose predominance varies from region to region, leave different traces in blood, and this makes identification even more difficult.

Lethal Fingerprint. Nonetheless, Siemens researchers suspected that this disease might be identifiable by means of a characteristic pattern, a kind of fingerprint. Two years ago Kavsek and her colleagues — in cooperation with physicians and laboratory diagnosticians — began to look for the malaria pattern in blood. "The problem is very complex," says Kavsek, who explains that the really difficult part is to find the right statistical procedures to use in evaluating the widest possible range of blood parameters for their suitability for malaria diagnosis.

But the researchers succeeded. In the end, a small number of parameters remained — and so did a simple formula that the ADVIA system can use in the future to search every blood sample for the fingerprint of malaria. "The selection of parameters is essential. The prognosis stands or falls on that basis," Kavsek emphasizes. By comparison to time-consuming preparations, the calculations performed within the device itself are now quick and easy, she says.

Sensitive and Specific. The Siemens team is now working to acquire and analyze datasets from India, Brazil, the Netherlands, and Africa. That's because the more data the researchers have as a basis for their formula, the more robust the automated analytical process will become. "We already have very good values for sensitivity and specificity," says Kavsek. In other words, ADVIA can identify malaria even if a very low number of parasites is present, and it hardly ever delivers false positive results.

In addition, Siemens experts are working on methods that will enable them to differentiate between various types of the disease. The ADVIA system could then be equipped with different settings depending on the analysis that is being carried out. Sometimes, for example, it might make sense to allow the device to register malaria even at the slightest suspicion of the disease. In other cases, it could be useful to recognize the various types of malaria so that they can be treated with greater specificity. "The beautiful thing about our method is that we don't need a new sensor or an additional measurement," says Kavsek. "All the information we need is already in the data." ■ *Ute Kehse*



Eyeglasses are taken for granted in developed countries, but they are in short supply elsewhere. These simple OneDollarGlasses can help solve the problem.

Seeing is Believing

The Siemens Stiftung (foundation) wants to improve the quality of life in developing countries with simple solutions that have a large impact, such as one-dollar eyeglasses.

Not everyone is born with perfect eyesight. Little Raduda certainly wasn't. A ten-year-old girl from Burkina Faso in western Africa, Raduda has suffered from a weak optic nerve since birth. "At school I always need more time for reading than the others," she says. Her wish for the future is to see the world with different eyes.

Raduda is one of more than 150 million people worldwide who suffer from weak vision, according to the World Health Organization (WHO); and this number is growing. Eyeglasses could provide a remedy, but although they are often worn as a type of costume jewelry in industrialized countries, they are a scarce commodity in developing countries and emerging economies. For people who generally have to live on less than two U.S. dollars per day, a pair of eyeglasses is unaffordable. And yet, according to the WHO, vision defects in poor countries result in the loss of approximately $120 billion of income per year.

When Martin Aufmuth, who teaches at a secondary school in Erlangen, Germany, heard about the problem of unaffordable glasses three years ago he decided to do something about it. "I've been involved in development aid for quite a while now," he says. His solution: "OneDollarGlasses."

His OneDollarGlasses are manufactured from about one dollar's worth of materials. Specially trained opticians can produce them easily and, above all, quickly in the countries where they are needed. "The production of the lens blank can be solved in ten minutes, and no electrical power is needed," says Aufmuth. The frames, which are made by hand on a specially-designed bending machine, consist of a flexible and robust spring-steel. Prefabricated, shatterproof lenses made of polycarbonate glass can be easily snapped into the frames.

Opticians in target countries are trained in local workshops to assemble, adjust, and distribution the glasses. Training is performed by EinDollarBrille e.V., an association of volunteers from Germany, and other non-profit organizations. "So far, we've trained opticians in three countries: Burkina Faso, Rwanda, and Bolivia," says Aufmuth. Following training, opticians go to villages with their assortment of lenses and finished frames. There, vision tests are carried out by locally-registered opticians or eye specialists, and the glasses are fitted to the wearer without any additional tools. The lenses in each optician's set come in 25 strengths, from -6.0 diopters to +6.0 diopters, and thus cover a number of levels of visual acuity. To ensure that local producers and sellers can make a living, the eyeglasses are sold for an amount equal to two to three days' wages in any particular country. In Rwanda, for example, this is approximately three to six dollars, depending on the version of the glasses. The business is self-sustaining, because sales of the glasses make it possible to purchase new material and earn a living. To make sure everything is less expensive, the lenses are symmetrical about a vertical axis. The same lens can thus be snapped into the left or the right rim across the entire range of lenses; therefore, only one standard shape is ever created and polished.

In poor countries, vision defects result in approximately $120 billion in lost income per year.

Quality of Life. Sales of the inexpensive corrective lenses began in 2012 in pilot projects. At the moment, only a few hundred people have purchased the glasses, but over 30 OneDollarGlasses opticians have been trained locally, so more and more people are being fitted with this affordable eyewear from day to day.

In 2013, the OneDollarGlasses invention was recognized with the "empowering people. Award" from the Siemens Stiftung (foundation). The award promotes engineering solutions that are simple but can nevertheless have a profound effect on quality of life. Ideally, the inventions can be integrated into entrepreneurial models and thus provide new income opportunities.

An international jury with members from the world's of business, science, and development cooperation gave the top honors to OneDollarGlasses out of over 800 submitted projects. As a monetary award, Aufmuth received €50,000, a sum that will help to further develop his invention.

The second place Stiftung award went to Dr. Moses Kizza Musaazi, an electrical engineer from Uganda for his "Maka Pads," inexpensive, biodegradable sanitary pads that are made locally out of natural material. They are also aimed at protecting women in poor countries from health problems and discrimination. He received a monetary award of €30,000 for his invention.

Third place and €20,000 went to David Osborne of Celsius Global Solutions in the United Kingdom. He developed the Jompy Water Boiler, a device that, when filled with water, can be placed between a cooking area and a pot. During cooking, the water that flows through it becomes hot enough to kill bacteria. This way, the water used during cooking can also be used as drinking water. The Jompy Water Boiler takes account of the fact that something that has long been available in developed countries, namely potable water, is by no means self evident in countries such as Kenya and Uganda.

With its "empowering people. Award," the Siemens Stiftung intends to identify technical and entrepreneurial approaches to solving problems and to promote broad use of such solutions in order to improve living conditions. Thanks to these inventions, and especially the stylish OneDollarGlasses, little Raduda can now enjoy an improved quality of life too — without spending a lot of money. ■ *Julia Hesse*

The Siemens Stiftung

Since it was founded in 2008, the Siemens Stiftung (foundation) has been supporting local and international projects in collaboration with partners around the world. The Stiftung's goal is to give people opportunities to participate in their communities socially and economically. It uses its endowment of €390 million to get involved in strengthening local culture, promoting education, expanding basic services, and encouraging social entrepreneurship. Together with its partners in the U.S., Colombia, France, Brazil, and Argentina, it cooperates in and supports responsible and innovative projects. The target regions for its projects are Africa, Latin America, and Europe.

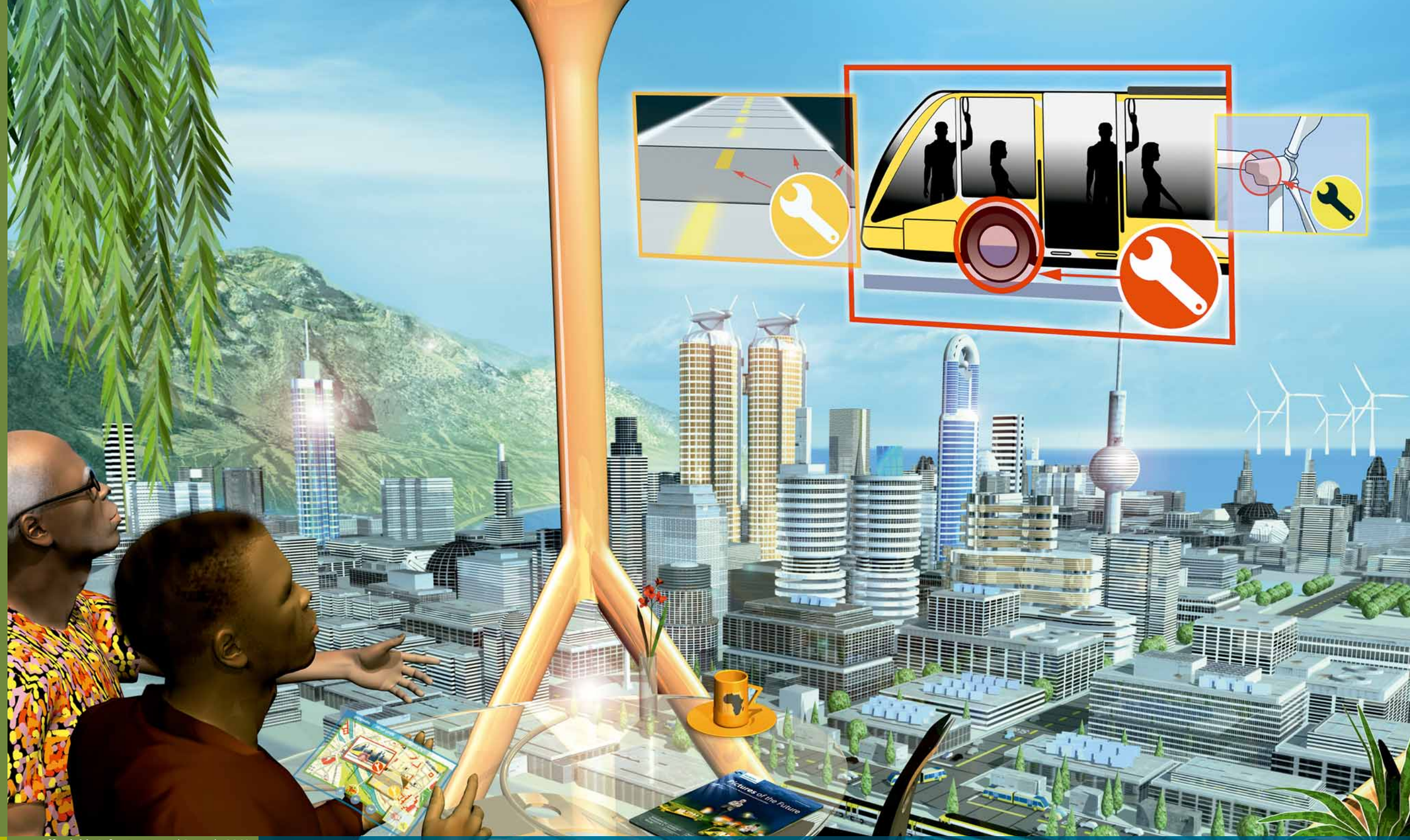
Highlights

55 South Sea Transformers
Unlike most other islands in the South Seas, the Fiji Islands generate electricity from hydropower instead of oil. New transformers are helping them save big bucks.

56 A Question of Financing
How does capital get to infrastructure projects that are worth supporting? Whether it's hospital equipment, power plants or trains that modernize public transportation systems, Siemens Financial Services' projects in London, New York, and China are worthwhile investments. Pages 56, 60

62 Two Continents in Five Minutes
A tunnel under the Bosporus is enabling much faster travel between the Orient and the Occident. Siemens equipped the tunnel with signaling and control technology. Now 75,000 passengers per hour can be transported in both directions.

66 Railroad to a New Start
Mozambique's infrastructure is being improved so that coal reserves, which are among the world's largest, can be shipped to market. Siemens has helped the country return to stability after civil war by electrifying a harbor and equipping a stretch of railroad with signaling and control technology.



Affordable Infrastructures | Scenario 2060

City of Sensors

2060 **How do you solve infrastructure problems before they pose a threat? Whether it's roads, power plants or public buildings, Lumumba Ewesa has an overview of his city's infrastructures, all of which are networked with radio sensors that recognize potential damage in advance and notify him in good time. His team then uses miniature drones to assess situations and plan responses. After that, replacement parts are individually manufactured using 3-D printing.**

A metropolis in Africa in 2060. Lumumba Ewesa's job is to supervise all of the city's infrastructures. Emerging problems are reported to him in real time by sensors before they become acute. Almost nothing has remained the way it was in his father's time.

"Give it to me! It's mine!" shouts Kijana Ewesa, his voice cracking. Soon he and his school friend, Karabo, are tussling, and the object of their desire — a wooden elephant the size of a fist — falls on the dry savanna ground. The two boys disappear under a cloud of dark brown dust. It's not the first time they've fought over the little elephant carved from limba wood — one of their few toys. That's why both of its tusks have long been missing.

Now it's almost 50 years later. Kijana is visiting his son Lumumba in the latter's office. The two of them are standing in a chic hexagonal glass tower, from which Lumumba wants to show his father exactly why he's known as the manager of all of this city's infrastructures. There's not much here to remind them of Kijana's childhood. "It's hard to believe there used to be only a wide steppe here with a few huts on it," says Kijana. The panoramic view from the window confirms that. There's not a trace of the thinly populated wide-open spaces of the past. Today, all they can see are polished apartment facades crowding together and glittering in the African sun. Slender high-rise complexes ra-

diate metropolitan flair, and industrial halls with big glass windows have replaced rural fields.

The steel-and-glass buildings are interspersed with well-tended parkland. On the outer wall of Lumumba's glass residence, a white willow rustles its dense, silky foliage in the wind. Only 50 years ago this water-loving tree would not have survived here, but today it's one of the city's most common trees, thanks to smart water networks and desalination. Nothing here has remained the way it was half a century ago. Only the brilliant sunlight and the mountains on the horizon are still the same as they were in Kijana's childhood.

Lumumba squints at the sunlight reflected from a glass table. From his office, he has to keep his eye on even the remotest corners of this metropolis, because he's the director of the authority that monitors urban infrastructures. He makes sure that any damage to roads, railroad lines or power plants is repaired promptly so that shutdowns and accidents can be avoided. The control center is his office.

"Fifty years ago it was easy to have an overview of the infrastructures that needed repair," laughs old Kijana. That's no wonder, because back then the city consisted of a hundred tin-roofed huts and a footpath. Kijana would repair leaky roofs, prop up crumbling walls, and mend torn fishing nets. He only acted once something was broken. "Today things are different, aren't they?" he asks curiously. "Yes, they are," Lumumba replies. "We detect defects and damage in the city before they even occur."

Kijana looks at his son questioningly, and Lumumba smiles at him, pulling his eye-communicator out of his pants pocket. This transparent device, which is as thin and flexible as a piece of felt, is Lumumba's "second brain." He squints slightly as he switches it on, and within fractions of a second it has projected the monitoring program for the city's infrastructures onto the glass wall of the office. "Railroad lines, roads, tunnels, public buildings, and power plants — all of them are equipped with radio sensors and networked," Lumumba explains. "We monitor their usability continuously in real time."

The projection gleams. The control system is currently showing three messages. "The most urgent one is in the middle," says Lumumba as he points to the windows. The sensors of a driverless electric bus have detected a defect in the vehicle's automatic braking system. The location is EW6 SX8, about 200 meters from the coast. "The location principle is simple: The whole city has been divided into a fine-grained network of coordinates that the sensors are connected with. We can localize problems in milliseconds," Lumumba says with pride.

There is a moment of silence. Kijana is upset: "Defective brakes in a moving bus? And you're standing here calmly without doing anything about it?" Lumumba laughs. "Don't worry! Our sensors not only detect defects but also anticipate them. This vehicle's brakes are still operating flawlessly. The defect will occur in about ten driving hours from now." Kijana is speechless.

Lumumba's team of maintenance technicians manages repairs. In order to get an overview of current defects, the team can look at every place in the city in real time, thanks to a fleet of miniature drones equipped with cameras. Like dragonflies, the drones silently hover over every corner of the city, taking pictures of their targets as though the engineers were directly on site. Lumumba's team is already assembling spare parts for the bus and switching on a 3-D printer in order to create complex individual components. "Because we can detect defects before they happen, we only need a small group of experts. Imagine us being a hospital. We'd only need a ward for preventive medicine, and the doctors in the emergency room would be practically unemployed," Lumumba says.

The projection is now drawing their attention to the next problem. At AC4 SX4 in the city center, a stretch of intelligent road surface, which uses light signals to manage the flow of electric vehicles, has to be renewed. A measuring unit has reported that the luminosity of the road surface has dimmed significantly. And finally, Lumumba has to send his engineers to TF7 SP2 in the southern part of the city because in two weeks there will be problems with the generator in a wind turbine. "Incredible!" exclaims Kijana, who is deeply impressed.

Suddenly the two men are startled out of their fascination. A noisy children's squabble can be heard from the adjoining room. "It's my boys again! Sorry, I'll have to step in," Lumumba says with a groan. "Of course," Kijana responds. "It's crazy. We can transform sparsely settled steppes into fruitful oases and predict urban damage before it even happens, but we still can't create children who don't quarrel." Lumumba shrugs. A small wooden elephant stands on a shelf behind him. Its tusks are missing, but so far no one has gotten around to replacing them.

■ *Ulrich Kreutzer*

Infrastructure investment in Europe has declined by more than 60 percent since 2007.

The Price Can Be Right

Infrastructure projects spur economic growth over the long term, but they also cost a lot of money to get off the ground. Intelligent technologies and flexible financing models can go a long way toward solving this dilemma.

What do Ho Chi Minh City and London have in common? Both have traffic problems, are susceptible to flooding, and need to invest heavily in their infrastructure. However, that's where the similarities end. Ho Chi Minh City is booming and will be able to plan and implement a modern and efficient infrastructure in the coming decades — practically from the ground up (p. 53). London, on the other hand, must maintain the infrastructure it has and expand it intelligently.

There are limits to what London can do here because the British capital has to take all of its existing systems into consideration in its planning. These include a maze of sewer tunnels from the Victorian era, which have been known to cause unpleasant surprises when foundations are dug. Then there are the rail lines, which were built in the 19th century, and the subway lines, whose stations occasionally have problems with leaky ceilings. Still, canals, tunnels, and aging power plants and hospitals can all be modernized — assuming funding is available. Indeed, regardless of whether you're building completely new infrastructure at a greenfield site or modernizing existing facilities (the brownfield solution), the biggest problem is usually the initial high level of investment required. Very few mayors these days can afford to spend billions of euros, pounds or dollars on major projects. In fact, many don't even have the funds to repair dilapidated structures.

The economic and financial crisis is still being felt in industrialized countries. Many of these nations have accumulated huge debt over the past few years. As a result, infrastructure investment in Europe has declined by more than 60 percent since 2007, according to a study by the BearingPoint Institute. The International Transport Forum reports that investment in transport infrastructure in western Europe has been decreasing since the 1970s. Investments in this area amounted to around 1.5 percent of gross domestic product (GDP) in 1975, but totaled only 0.8 percent of GDP in 2009. Moreover, nearly 30 percent of infrastructure investment is now being used to maintain existing systems (p. 64).

Economic growth has also slowed in emerging markets, which means new infrastructure projects might take longer to complete than originally planned. For example, the number of vehicles on the road in Indonesia's capital, Jakarta, increased by 22 percent each year between 2005 and 2009, even as more and more roads fell into complete disrepair and became unusable.

Realizing a Dream. Things don't always have to be this way. For example, despite tight budget constraints, Turkey decided to invest extensively in Istanbul and make a 160-year-old dream come true — the construction of a tunnel underneath the Bosporus (p. 62). The 13-km tunnel entered service in October

2013. It now accommodates commuter trains that run at two-minute intervals and can transport up to a million passengers per day. Siemens supplied the tunnel's signal and control systems, including everything from transmission cables to complex system operations technologies.

In the long term, such investments can recoup their initial costs many times over. Commuters spend less time in traffic jams and thus have more time for productive activities. Automobile-related air pollution and noise may be at least somewhat reduced, and associated respiratory illnesses may decline. Productivity thus tends to improve, which, over the long term, has a positive impact on economic growth.

The benefits of investing in infrastructure become noticeable only after years — but the costs are felt immediately.

The problem is that the positive economic effects of such infrastructure investments only become noticeable after several years, while their costs are felt immediately and therefore tend to scare off local governments. That's why flexible, long-term infrastructure financing models are so important.

New Rail Cars. Such a model is helping London modernize the Thameslink rail line, which is 225 km long, runs from north to south through the city, and connects many suburban areas with the center of London (p. 56). The line carries 40 million passengers each year, but the trains and some of the stations are rather old, as is the line itself. Thameslink is therefore now being completely modernized in one of the biggest infrastructure projects in Europe. Among other things, Siemens is building 1,140 new rail cars.

The Thameslink project is not being directly financed by the government. Instead, the project partners will recoup their investment over the next 20 years through fare revenues. This setup was made possible by a complex financing solution that spread the investment costs over two decades. Siemens contributed more than 400 million British pounds to the project via its Siemens Financial Services (SFS) unit. Thanks to its financial strength, SFS was also able to make certain guarantees that few banks would be willing to offer at the moment, including a fixed interest rate for the entire term of the Thameslink financing period. This will benefit British taxpayers and future Thameslink riders, since it ensures that costs will remain predictable over the long term.

New Transformers for Fiji. It's not just the world's biggest cities that illustrate how investment in suitable infrastructures is money well spent. Residents of Fiji, for example, rely on a hydroelectric power plant that offsets oil imports. The result is that the island country is saving approximately $423 million per year. Siemens modernized the plant's transformers in 2013 (p. 55).

And in Mozambique, a 912-km rail link is now being built from the port city of Nacala to the interior of the country, which harbors huge coal deposits. Without a reliable transport connection, the nation would never be able to exploit this valuable resource. Siemens is helping out here by supplying signal and control technologies. The company is also installing a cost-effective power supply solution at the harbor (p. 66) that includes power distribution stations. These are installed in containers known as E-Houses. Built in Germany, the containers are fitted with switchgear and power distribution equipment before being shipped to their destination. This reduces the costs of assembly, installation, and commissioning. "E-Houses are 20 percent cheaper than conventional building solutions for power distribution," explains Jean-Philippe Macary from Siemens Infrastructure & Cities.

Modernizing Luanda's Grid. Infrastructure costs are also an important issue for Luanda, the capital of Angola. "Only 40 to 50 percent of households in the city have electricity," says Helder Adão, president of EDEL, the local power company. "A lot of people are moving into the outskirts of Luanda, and entire districts are rising up without having been planned," he adds. The existing grid is overloaded, and this frequently results in power outages.

Engineers need to know which substations are particularly unstable, which are operating normally, and where bottlenecks might occur in six months if growth continues. In order to provide answers to such questions, Siemens mapped the entire grid in Luanda and developed a computer model that helped engineers determine the impact specific investments would have on the overall system. Thanks to the recommendations made by Siemens, the city can now modernize its grid infrastructure in a more efficient manner (p. 68). Money isn't the only issue here. It's also very important to utilize intelligent approaches when developing and installing new infrastructure and improving existing systems. In other words, good infrastructure doesn't have to cost a fortune — but it can improve the fortunes of an entire city or country.

Andreas Kleinschmidt

Maintaining existing infrastructures is expensive. Targeted investments in upgrades can avoid far more expensive repairs further down the line.

Whether it's power plants or transportation, Thai Lai Pham knows where Ho Chi Minh City needs to catch up.

New Life in Vietnam

Ho Chi Minh City, Vietnam's largest metropolis, is facing massive challenges, especially where its infrastructure is concerned. Siemens' Thai Lai Pham is advising the city.

Thai Lai Pham was three years old when the Vietnam War ended in 1975. He still remembers the postwar years very well — hunger and poverty, the oil lamp he used to read by because there was no electricity, and getting up at 3 a.m. with his parents to go get fresh water. He also remembers occasional strenuous trips from his hometown, Hue — the former capital of the empire, located in the middle of Vietnam — to Saigon, which today is called Ho Chi Minh City. It was a distance of 1,000 kilometers, and the trip took three days and two nights.

Dr. Lai, as his coworkers at Siemens respectfully call him, is standing at a window in his office in Ho Chi Minh City and looking at the gigantic stretch of wasteland on the other side of the Saigon River. Here, the city government has torn down old houses in order to build a new financial district. Much has changed in the city in addition to its name. Electric light and running water have become a normal part of life for its inhabitants. The economic reform policy known as "Doi Moi" (New Life) has decreased the poverty rate from 70 percent before the launch of the program in 1986 to ten percent today.

Many of the old problems have disappeared, but new ones have arisen. One of them is chaotic traffic. About 4.5 million mopeds clog the streets and create massive air pollution. Fortunately, there are only about half a million cars in the city. If those figures were reversed, the transportation network would break down completely. There is still no rail-based public transportation, such as a subway system, either in Ho Chi Minh City or in the rest of the country — even though Saigon had a steam-operated streetcar system as early as 1881 and an electric streetcar system in 1923. And the bus fleet in Ho Chi Minh City is hopelessly overcrowded.

"It's incredible how quickly everything here is changing," Pham thinks every time he drives his car home from work. If you've been away for just two weeks, on your way home from the airport you're sure to see new shells being built for the ever-popular high-rise apartment buildings. The culture shock was especially great for Pham, who is now 42, when he returned to Vietnam two years ago. He had emigrated to Germany with his parents when he was ten years old.

Pham studied electrical engineering in Munich and received his M.A. and Ph.D. degrees in Princeton, New Jersey while working at Siemens Corporate Technology's research center there. He subsequently worked at a business consulting company and then at Siemens in the areas of IT, corporate strategy, medical technology, and gas turbines. At that point Siemens was looking for a new country director for Vietnam, and Pham turned out to be the right man for the job. He has been familiar with the country, the people, and the language since his childhood. Nonetheless, it wasn't easy for him, his wife, and his two children to adjust to the country once they got there. "Life in Vietnam has completely changed," he says. "Of course this also has its positive side. Above all, the infrastructure in Vietnam has improved considerably."

All the same, the infrastructure is still far from being good enough. Together with the Society for International Cooperation and the

People's Committee of Ho Chi Minh City, Siemens published a study called "Ho Chi Minh City 21," which sums up the city's challenges. One of them is rapid urbanization. The city's population is growing by about 200,000 people annually. In 2013, about 33 percent of Vietnamese lived in cities, but by 2050 that figure is expected to be 60 percent. Another challenge is the increase of traffic despite the lack of an adequate public transportation network. There's also the city's precarious geographic situation. Almost half of its area lies less than one meter above sea level and is at risk of flooding, partly because of climate change. New satellite towns are continually being created in swampy areas. The study concludes that the city must invest considerable amounts in new infrastructure. In addition to flood prevention and an improved water distribution system, it needs an extensive subway system and an active traffic management program.

Diplomacy Required. An initial subway line is being built, and a second stretch is being planned. A master plan for public transportation calls for the construction of a total of seven lines. Siemens has been advising the city for a decade now on the Line 2 project. The call for tenders will probably be issued in 2014. Such plans cannot be realized without expertise from abroad. As a result, the 300 Siemens employees who are working under Pham's leadership in Vietnam are valued as contact partners for major infrastructure projects. Pham, who is not only the country manager but also the City Account Manager for Ho Chi Minh City, has to do a lot of persuading within the municipal administration. He's also in demand because of his professional expertise. When business deals are being negotiated, potential customers ask very detailed questions about technical and planning issues. And they prefer to ask the boss, according to the traditions of Vietnam's hierarchic social system.

People who don't know the country's business culture as well as Pham does can easily sink into despair. "Everything is in flux, the organization is often impenetrable, everything is done at the last minute — but then it somehow works after all," he says. It's not always easy to see how areas of responsibility are divided between the federal government and the provincial and city administrations. Information about who is really in charge of major infrastructure projects is often a mystery to outsiders. "In many cases there are hidden players," says Pham. As a result, balancing opposing interests requires lots of diplomacy.

In 2013, about 33 percent of Vietnamese lived in cities. Forecasts suggest this figure could reach 60 percent by 2050.

Vietnam is still regarded as a country that is plagued by corruption. In the rankings published by Transparency International in 2013, it occupied place 116, out of a total of 177 countries. However, these rankings record only the public perception of a given country's level of corruption, because there's no way to measure corruption objectively. "In any case, Siemens insists on conducting clean business dealings," Pham says. That has long been common knowledge.

Today, Siemens can point to considerable successes in Vietnam. For example, it is the market leader in the field of combined cycle power plants; 45 percent of the energy generated by such plants in Vietnam comes from Siemens systems. The Nhon Trach 2 combined cycle power plant, which generates 750 MW, was commissioned three years ago. Its efficiency level of 58.5 percent is the highest in the country. Siemens and a Vietnamese partner built it in a record-breaking 28 months. In addition, Siemens equipped the Bitexco Financial Tower — which CNN has called one of the 25 most beautiful high-rises in Southeast Asia — with automatic air conditioning, fire prevention, and security technology. Ultramodern computer and MR tomographs from Siemens are being used in the city's leading hospitals, almost all of Vietnam's breweries are equipped with the Siemens Braumat solution, and the new National Assembly receives its energy via conductor rails from Siemens.

Childhood Dream. "Of course, price plays a major role in negotiations, especially with private clients," says Pham. Competition from China and Korea is a new driving force in the market. In order to be competitive, Siemens is now manufacturing many products, such as transformers and computer tomographs, in China, India, and other countries in the region. Conductor rails are produced in Vietnam itself. Siemens Financial Services occasionally helps to finance projects. An example is a bus with a hybrid drive that the company has developed in cooperation with the Vietnam Motors Industry Corporation. Whether the prototype will go into large-scale production and then help to mitigate Ho Chi Minh City's traffic problems will probably be decided in the course of 2014.

Pham's return to Vietnam was the realization of a childhood dream. But when, or whether, he and his family will return to Germany is still uncertain. Before he returns, Pham would like to complete his mission. "I would like to help the land of my birth move toward the status of an industrialized nation, and to help Ho Chi Minh City become a metropolis that's a pleasure to live in," he says.

Bernd Müller

Four 45-ton transformers have been installed deep in the jungles of the Fiji Islands.

South Sea Transformers

Unlike most other islands in the South Seas, the Fiji Islands generate electricity from hydropower instead of oil. Siemens has replaced four 30-year-old transformers. The replacements came all the way from Austria to the Fiji Islands.

It's the beginning of August 2013. This is the dry season on the Fiji Islands — or rather, what passes as a dry season in a very wet part of the world. The average temperature is 25 degrees Celsius with humidity of over 70 percent.

Project Manager Federico Tocasuckyl has been waiting for this moment. It's the ideal time for him to carry out his assignment. The rainy season will begin in October, and he has until then to get four new transformers up and running.

He and his team are standing in the middle of the jungle. In front of him, a 45-ton, four-meter-high transformer is being maneuvered out of its mount. For almost 30 years, this Siemens transformer has been in service at the Monosavu hydroelectric plant.

The plant's operating association, the Fiji Electricity Authority (FEA), has decided to replace the transformers. "Their electrical properties have deteriorated," explains Hasmukh Patel, FEA's CEO. "Of course the replacement process must be carefully managed in order to avoid the risk of disrupting the island's power supply."

After the decision for replacement was made, the project was opened to international bidding, and Siemens won the contract. The Monosavu plant's four 20-megawatt turbines generate electricity at 11 kilovolts. The power is then converted to 132 kilovolts by the transformers before being transmitted to the western and central areas of the main island Viti Levu. Each transformer is connected to a single turbine. So if a transformer is offline, the corresponding turbine is also not available for operation, which is why the transformers are being replaced sequentially.

The heat and humidity cause beads of sweat to form on the brows of the team members, who are wearing protective cloth-

ing. They begin by using hydraulic pumps to move the first of the old transformers, then heave it onto a lowboy trailer for transport. A new transformer is already waiting in front of the power plant. In this way, one old transformer after the other is removed and replaced. "Up to now, things have gone exactly according to plan," says Tocasuckyl proudly.

That things are going so smoothly was not a given. After all, the new units have had a long journey. They have traveled all the way from Linz, Austria, to Fiji. They were at sea for almost six weeks. In Singapore they had to be loaded onto a different container ship because not many ships deliver to the Fiji Islands. The situation with air traffic is very similar. "During their trip, we kept track of the transformers with the help of GPS transmitters," says Tocasuckyl.

Big Savings. The journey continued from the harbor of the capital city Suva to Wailoa in the island's interior. This trip usually takes about two hours by car. But when a heavy transporter is required, an entire day is needed for each transformer. Before the delivery, the steep roads had to be improved and widened in some cases in order to make smooth delivery possible. Long stretches of the roads aren't even paved. In order to get to know the route and its characteristics, Tocasuckyl and his team took two days to transport the first transformer overland. When the transporter stopped for the night, the valuable metal colossus had to be guarded to protect it from copper thieves.

The Monosavu hydroelectric plant is something special in the region because, unlike many Pacific Islands, which generate their power from fossil fuels, its fuel is renewable. "Monosavu supplies about 400 gigawatt hours per year," says Nizam-ud-Dean, Chairman of the Board of FEA. "So far, this has saved around $800 million worth of oil. The price of electricity in Fiji would be much higher if we didn't have this hydroelectric plant; in fact, the entire country would be affected."

Today, all four of the new transformers are in operation. Looking back, Project Manager Tocasuckyl says, "I'll always remember the last day, when the fourth and last transformer went into operation. We were on site together with the FEA representatives and they turned to us and said, 'Thank you.' That was a very special moment for me."

If the new transformers are as reliable as the old ones, the Fiji Islanders will have another 30 years of inexpensive and environmentally friendly hydroelectric power at their disposal. ■ *Maximilian Heinrich*

Basil Wetters works at the Siemens Bank in London. His job involves business deals worth billions of pounds.

Projects for People

Railroad lines, power plants, hospitals — investments like these are crucial, but often we're told that the money for them just isn't there. Others say there is a huge amount of money struggling to find its way to good projects. Siemens Financial Services helps to bring worthwhile projects and the necessary capital together. Major projects in London and New York provide examples.

Black cabs are whooshing along Appold Street, and young men in dark suits throng the sidewalks. Basil Wetters is leaving his office in the heart of the City in London, the financial district of the UK's capital. Today he's wearing a blue pullover, brown shoes that resemble hiking boots, and a plastic wristwatch that can be bought online for ten British pounds. If you were to meet him outside on the street, you'd never guess that he's involved in business deals worth billions.

Wetters works for Siemens Financial Services (SFS), more precisely for the Siemens Bank. He's a finance lawyer by background, and he has been employed by Siemens for 15 years. Recently he swapped his legal hat for that of a financier. His previous employers include a development bank in India. "Lots of money is circulating all over the world," he says. "Interest rates are low, so people are eager to take out loans." But what are people doing with all this money? The simplest answer, put briefly, is that some people invest it and some speculate with it. In fact, a lot of money flows into speculative investments that are expected to produce quick wins — so-called "hot money." In some trading rooms in London, positions are held for only fractions of a second before being sold to further investors — in the hopes of making a profit. By contrast, there is too little investment in projects that create long-lasting values, such as railroad lines, power plants, and hospitals. "And yet it is these very projects that directly improve the living conditions of many people around the globe and at the same time make a long-term contribution to economic growth," Wetters says. "In many cases, these projects are even more profitable than speculative investments. You just have to have patience. Money doesn't always find the right path on its own. You have to help things along." In a sense, this is the definition of Wetters' job: helping money to find the right path.

"We're like a normal bank," he says. "However, at the Siemens Bank we're just a bit different. We want to be profitable, of course, but our attitude is that money isn't everything. Behind every transaction there's a project worth working for."

What do those people do with all that money? Put simply, some of them invest, others speculate.

One example is the British railroad line known as Thameslink. It's 225 kilometers long, crosses London from north to south, and connects numerous suburbs with the City. About 40 million passengers use it every year. The line was not originally designed to accommodate so many passengers, so it is now overcrowded — something that can also be said about many other parts of the London mass transit system (see *Pictures of the Future,* Spring 2013, p. 85).

The "Thameslink Programme" is one of the largest infrastructure projects in Europe. Plans call for more trains, carrying more passengers. In addition, two new major depots are being built, and Siemens is constructing 1,140 regional train cars. The project contracts, covering supply, finance, and subsequent maintenance of the carriage fleet, have a present net value of about 2.6 billion British pounds. For projects of such huge dimensions, customers of course do not simply place an order and hand over a check because the funds are public and the public sector is typically strapped. "Buyers, suppliers, and banks work together to minimize the cost of financing such projects. The resulting solutions can turn out to be so complex that they are not much less complicated than the engineers' achievements," says Steve Ellison, one of Wetters' colleagues. "However, all this effort is worthwhile for the railroad's customers and the taxpayers," he adds.

Solving Difficult Problems. Customers are increasingly looking for a good overall package, and a major aspect of that is the question of how and when the order is to be paid for. "We had to deliver world-class trains and depots and offer a world-class financing arrangement," says Ellison. That was no small requirement, but Ellison has many years of experience in the area of project financing, and he likes to solve difficult problems.

"First of all, we established our own company, the Cross London Trains project consortium (XLT), which is buying the trains. Along with two other financial investors, we too have brought funding into this enterprise. SFS has provided more than 400 million British pounds," Ellison explains. In the future, private train operating companies will be able to apply for a Thameslink franchise every seven to ten years. Companies that operate this line will have to lease the trains from XLT for the duration of the franchise with the investment being repaid over 20 years. In exchange, Thameslink commuters will get brand-new trains operating at increased frequencies.

The sensitive part of the negotiations involved another theme, the financing of the train depots, which were part of the overall package. However, the funds would be needed only at a later stage. The team needed to prove the money was there by having a guaranteed credit line called a "commitment," that would only be used several years later. Without a commitment of this kind, the planning of the entire deal could not have proceeded. No railroad depots would mean no trains.

In the past, banks often offered such commitments. For a surcharge, they would provide a loan for a set interest rate in the future. However, banks have become more cautious, and it is now much more difficult and expensive to obtain commitments. The shock of the financial crisis is still affecting many financial institutions; a few years ago some banks simply had no more money to lend. Now they are worried that money might become scarce again in the near future. In this kind of situation, banks are reluctant to make any promises for the year ahead.

Moreover, regulators require banks to have more equity capital. Some banks are now holding on to money that they previously would have lent to customers. In particular, long-term loans are being granted either with higher surcharges or not at all. "This is exactly where SFS stepped up to the plate," says Ellison. There and then, it decided to guarantee the credit line for the train depots and to fix an interest rate that would apply for 20 years. Now there were no more obstacles standing in the way of the deal. The first trains will be delivered in 2016. "There is a lot to learn from the Thameslink transaction," says Dr. Andreas Schumacher, who heads Strategic Development at SFS in Munich. "Our customers want to have a good overall package with a good financing solution. That's clearly what they tell us. Increasingly, they look beyond trains, turbines or scanners — what they're interested in is the benefit that comes from using them. In other words, they look for transport capacities between two places, or a certain amount of electricity for a certain period of time, or 20 computer tomography scans per day." So does it really make sense to buy and own equipment? Or will the customer receive better value-for-money by leasing the equipment or simply paying to use it?

If money doesn't find the right path on its own, someone has to show it the way.

These questions can be answered only if the total cost of a purchase — including the costs of financing it — is transparent. In the case of large transactions, SFS is therefore on board from the very start in order to provide advice to Siemens customers and prospects. In the case of Thameslink, the decision was clear: The trains will be leased to the railroad operators, because that is ultimately the most economical solution. The overall package was the key factor that helped Siemens win this business. The same can be said for a major project in the U.S., except that it involved turbines rather than trains.

Financing Power Plants. Bob Simmons' workplace is an office on Park Avenue, right behind Grand Central Station in New York City. Here, the taxis here are yellow rather than black, but the subway system, like the Underground in London, is showing its age. And the crowding in the subway cars is just as bad.

Simmons is General Partner and Treasurer of Panda Power Funds. The company builds, and is planning to run, power plants. It looks for appropriate sites, applies for all of the necessary authorizations, and chooses the most suitable technology.

"In this business model, every cent counts. If you make a mistake at the beginning of your calculations and the investment costs get out of hand, that will have negative effects during the entire lifetime of a project — and in the case of power plants, that means decades," says Simmons. Panda therefore pays close attention to two things: optimal project financing and highly efficient technologies that promise cost-efficient plant operation.

Panda often chooses Siemens H-Class gas turbines, which can reach over 60 percent efficiency when operated in combination with steam turbines. By comparison, the average efficiency of fossil-fuel power plants in the U.S. is only 33 percent. "We've been a Siemens customer for a long time. It's natural for us to talk about the financing of our projects. When we plan new projects, we get SFS on board as early as possible," says Simmons. "The Siemens people know what we need, and they are very professional. Over the years we've developed great trust in them. For example, I've known Guy Cirincione for 20 years."

Decades-old Wagons. Cirincione's workplace is not very far from Simmons' office, but it's in New Jersey, on the other side of the Hudson River. This is where SFS has its U.S. headquarters. To get to the inconspicuous Siemens offices from Manhattan, one can chose to take a commuter train with cars that are decades old. "The U.S. transportation network urgently needs investments," says Cirincione. "That's obvious. But the U.S. energy infrastructure is also antiquated. That's something people realize only when there's a blackout. And this is where Panda enters the picture." The U.S. clearly needs new power plants. And Panda is building them — especially gas-fueled power plants, because gas prices in the U.S. have decreased considerably in recent years.

Panda's partner of choice is Siemens, in part because of its creative financing solutions. Guy Cirincione reports that during the negotiations he is always asked the same question: "Guy, how can you make the overall package even more interesting for us?" And that's when his work really starts. For example, for the most recent joint project Panda required something known as a "delayed draw tranche." This is a loan that is to be paid out only later, because for the construction of a power plant not all of the money in the capital structure is required immediately. It's a situation similar to that of Thameslink. If a client were to accept all of the capital at the

Many of New York's subway stations are worn out.

London public transit riders will benefit from Thameslink's new trains from Siemens. Power networks (top) also need continual investment.

A Business that Builds Bridges to the Future

Siemens Financial Services (SFS) is essentially Siemens' bank. Its approximately 3,000 employees have three missions:

- They support Siemens customers and thus Siemens' business by providing them with financing solutions. These solutions range from standardized leasing models to complex structured project financing. Demand is growing. Since the onset of the financial crisis more and more clients have had difficulty coming up with high upfront capital.
- They manage financial risks for Siemens. Such risks can arise from exchange rate fluctuations, for example. SFS performs treasury functions, meaning it ensures that Siemens always has liquidity and can pay its bills. SFS also combines for Siemens all of the risks that can be insured. In this way, Siemens gains better conditions and has higher transparency for its insurance contracts.
- To a limited extent SFS also offer financing solutions that are not linked to the sale of Siemens products or services. This external business helps SFS to keep in touch more closely with the overall financial market. This helps SFS identify trends and offer conditions in line with the market for all its business. According to a study conducted by the Bearingpoint Institute in Amsterdam, infrastructure investments in Europe have plummeted by approximately 60 percent since 2007. The public sector has had less leeway for investment since the most recent financial crisis, and private investors often shy away from infrastructure projects because of the long investment periods involved. As a result, the importance of financing solutions for infrastructure customers in the public and private sectors alike is increasing. SFS can, metaphorically speaking, build bridges for these customers. Thanks to financing solutions, customers can realize projects that would never have existed otherwise: railroad lines, power plants, hospitals — investments that are genuinely needed and that create favorable conditions for sustainable growth. And SFS is earning money. In 2013 SFS' income before interest and taxes (IBIT) was €409 million.

Chen Yang takes a train to visit his customers — hospitals looking to lease modern technologies.

Health Care on the Installment Plan

More and more Chinese are turning to private clinics for medical treatment. However, hospitals in China often cannot get loans for the purchase of imaging systems such as CT scanners. In order to be able to obtain new equipment quickly, clinics often decide on leasing models from Siemens Financial Services.

beginning of the project, he would have to pay interest on it from the very first day, even though many bills would not need to be paid until months or years later. In such cases it would be better to accept the loan in a series of payments. However, infrastructure investors in New York have to cope with similar challenges as those in London. "The banks have become very cautious regarding their loan decisions," says Simmons. And if banks are risk averse, money can be hard to get.

Risks "Here and Now." The loan to Panda was assigned a B/B+ credit rating by the rating agencies — a rating that some banks regard as risky. Other investors, such as institutional investors, are happy to take on such risks in their books, but they almost always decline requests for delayed tranches. In other words, it would be practically impossible for a project with this kind of credit rating to get a "delayed draw tranche" for a loan on the present market. Or it could get one only for an extremely high fee.

At this point, Siemens helped out by guaranteeing a delayed credit line of $50 million. "Obviously, we look closely at a commitment of this size before we say yes. We don't ignore the rules of the market just to get the business for Siemens," explains Cirincione. "On the other hand, SFS is organized differently from a bank or an insurance company. A loan of this kind fits in well with the SFS business model." And that translates into a competitive edge for Siemens.

Thameslink and Panda demonstrate that when it comes to major infrastructure projects, well-thought-out financing solutions have become part of the product. According to Cirincione, financing solutions are just as important to customers as the energy efficiency of a suburban train or the shape of a turbine's blades. "Siemens doesn't simply sell turbines to Panda," he says. "We sell well-financed turbines. " Basil Wetters in London sees the situation the same way. He says that the decisive factor in the decision to grant the Thameslink contract to Siemens was its attractive overall package — the combination of best product and best financing solution.

Wetters glances at his plastic watch; his working day is almost over. Soon he'll join the hordes of men in neat suits and squeeze into the Tube. Have these infrastructure deals made him rich? "Honestly, I have enough money," he says. "If I only wanted to maximize my personal income, I wouldn't be at SFS. But to me doing something valuable each day is important. Money isn't everything." ■ *Andreas Kleinschmidt*

Chen Yang is once again sitting in the train that goes from Shenyang to Changchun. The local orthopedic hospital would like to place yet another order. This time it's for two computed tomographs, a magnetic resonance tomograph, and three X-ray units. The total price tag will read around RMB 15 million (about 1.8 Mio Euro). But the hospital doesn't want to pay — at least, not yet. And that is exactly why Chen Yang is needed.

Chen Yang works for Siemens Financial Services (SFS). SFS helps Chinese hospitals finance new equipment. Most private clinics are like Changchun Orthopedic Hospital (COH) in one respect: They decide not to buy imaging equipment but to lease it instead. This way they can pay off the purchase price in installments spread out over several years.

The COH, which is situated in northeastern China, has already leased equipment with a total value of RMB 31 million (€3.6 million) from Siemens. Now, it's coming back for more. The number of private hospitals in China is expected to rise in the coming years. Increasing numbers of Chinese are looking for good healthcare. Obtaining appointments in state hospitals is not always easy. The increasing numbers of elderly patients also increases the pressure on the healthcare system.

In 2012 the Chinese spent approximately RMB 2,837 billion (€332 billion) for healthcare services. By 2017 that figure may more than double. China's financial leasing market is enjoying double-digit growth rates. On the whole, the growth of the health care sector is not the only reason for this. China's government is tightening credit. Chinese banks are thus currently more reluctant to lend money than they were in past years. When they do provide loans to the healthcare sector, it is primarily to state-run clinics. Consequently, most private clinics have to find financing elsewhere.

Leasing is a good alternative, although it appears to be slightly more expensive at first glance. "The reference interest rate from the Central Bank of China for one-year loans is approximately 6.5 percent. However, the 'all-in' cost of credit financing is not much cheaper compared to a lease," explains Chen Yang. Also, leasing enables customers to manage cash flows more flexibly.

The number of leasing companies has more than doubled in the last two years, and competition is fierce. "Setting up long-term partnerships with hospitals such as COH is crucial, but at the same time difficult," Chen Yang says. "COH received several financing offers from our competitors when it was in the process of buying health care equipment from Siemens for the first time. To secure the deal, we commuted between our offices in Shenyang and the hospital in Changchun many times to discuss and understand COH's exact requirements. As a result, we were quickly able to design a tailor-made leasing solution," adds Chen Yang.

Value for Money. The train arrives at Changchun's station. After a short taxi ride, Chen Yang meets Chen Wei, COH's director. A steaming cup of tea is waiting. "Of course we negotiate the price every time we discuss new equipment," Chen Wei says. "I receive offers from banks and other leasing companies, but price is not the only factor that is important for us. We are really looking for a long-term, reliable partner to provide the best service overall. So we consider speed, convenience, and people. Siemens is quite simply a company you can trust and that meets our expectations."

He adds that, "the leasing solution from Siemens will actually cost me a bit more compared to the traditional mortgage loan, that's true. But with an SFS lease I'll receive everything from a single source — the equipment and the financing. I think that's real value for money, and that's why I'd like to continue working with Siemens and SFS in the future."

There will probably be many opportunities for collaboration, because COH plans to open new clinics. And for Chen Yang there is no shortage of work either. He recently became responsible for a team of six. As soon as a potential customer gets in touch, colleagues from Siemens' Healthcare sector tell them about it so that they can quickly make an offer. Nevertheless, this is not an easy task since China does not have a central register with reliable assessments of customers' credit ratings, explains Chen Yang. Therefore, he needs to make a good estimate as to whether the use of equipment will pay off for a prospective customer — that's what ultimately determines whether they can pay their leasing installments.

In 2012 the Chinese spent around €332 billion on healthcare — a figure that is expected to double by 2017.

One source of information for the SFS risk team crunching the numbers is hospital financials. But industry experience and a quick estimate play an important role, too: What equipment does the customer want? How many beds does the hospital have? How big is the catchment area? What is the average income of the patients in the catchment area?

Assessing creditworthiness is much easier of course, when dealing with a repeat customer, like COH. The people who are negotiating the deal know, appreciate, and trust one another. Also, COH has a positive track record with SFS. What's more, it's got big plans for the future. "We want to expand within our home province of Jilin. But we're also building clinics in other parts of the country: in Xi'an, in Kunming, and in Haikou," says Chen Wei. COH is targeting the market segment for highly specialized orthopedic clinics, which is growing especially fast. The regional authority of Kunming is promoting the construction of hospitals because the level of care is considered to be below the average for the province. The situation is similar in Xi'an, a city in the interior of China with a population exceeding eight million and in need of more specialized clinics.

Chen Wei says that, in spite of the current "gold rush" mood in the private healthcare market in China, he won't be making quick profits. "Orthopedic clinics require particularly high initial investments. Over the course of time, however, these are balanced out by higher margins, making such clinics very interesting in the long run. But at first there are often challenges, and that makes many investors hesitate. With a strong and reliable partner such as Siemens, we can get through this lean period much better," he says. Chen Yang and Chen Wei finish their tea. Once again, they've concluded a deal. Chen Yang will now head back to Shenyang. He's convinced that this won't be the last time he travels this route.

■ *Andreas Kleinschmidt*

Teaching Roads to Talk

One of the ways to make road traffic safer, more efficient, and more environmentally friendly is to enable cars to communicate with the infrastructure. Siemens is supporting pilot projects that will help make this possible.

In the future, vehicles will be able to share information with the transportation infrastructure in real time concerning the flow of traffic, road accidents and construction sites. Numerous research projects have shown that such "cooperative systems" are feasible.

For example, on a 45-kilometer test track at a telematics testing ground in Vienna, Austria (*Pictures of the Future*, Spring 2013, p. 104) various applications are being tested. They include notifications of potentially dangerous situations, traffic jams, reminders of warning signs, and speed-reducing devices inside the vehicle.

European automakers in the Car2Car consortium, an organization designed to promote open communications among vehicles, have already committed themselves to introduce vehicles equipped with cooperative systems in 2015. Road operators are now following suit. In June 2013 the transportation ministers of Germany, Austria, and the Netherlands signed a declaration of intent concerning their joint introduction of cooperative systems. In cooperation with partners from industry, warnings concerning road construction sites will initially be set up on highways between Vienna and Rotterdam. Specially equipped construction-site trailers will use WLAN or mobile radio networks to send information to a transportation center, which will then relay it to vehicles. In turn, cars that are equipped with the necessary technology will send information about their current positions, as well as additional data on traffic movements or weather conditions, to the transportation center.

In the near future, vehicles will communicate with the transportation infrastructure.

In Austria, all of these measures are being combined in the ECo-AT project, which is designed to develop the specifications for all of the products and services for cooperative systems. These systems will then be tested on an approximately ten-kilometer stretch of road. Siemens is providing hardware for the test track and control center, as well as for the roadside units, the onboard units, and associated communications software.

Naturally, data security will be a key part of tomorrow's cooperative systems landscape. Plans call for all of messages related to safety or transport technology to be equipped with a standardized PKI (Public Key Infrastructure) code. Every vehicle's ID will be anonymized in order to keep communication confidential. Starting in 2015, the entire corridor between Vienna and Rotterdam will be equipped with cooperative systems.

■ *Nicole Elflein*

Istanbul's Marmaray rail Tunnel will ease pressure on chronically congested bridges and ferries.

Two Continents in Five Minutes

For 160 years politicians have dreamed of building a tunnel under the Bosporus Strait, but the difficulties were daunting. Engineers have now found the solution. Today, about a million people commute daily through the Marmaray Tunnel between Asia and Europe.

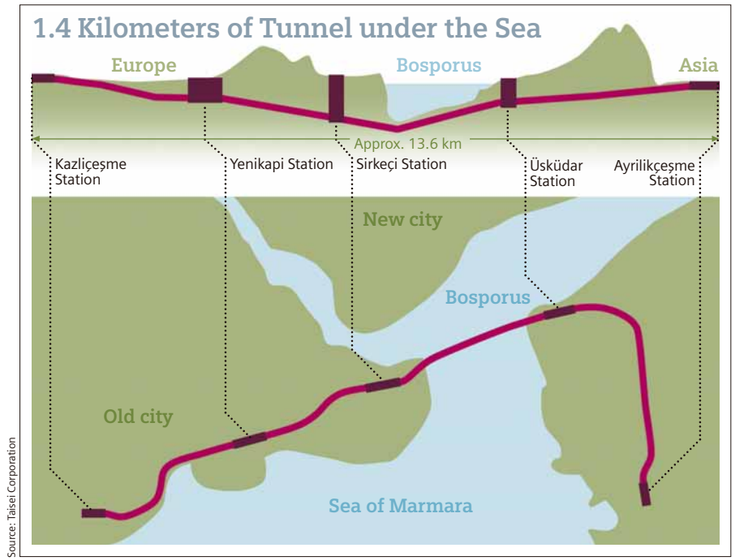
The two young women are ready for the big moment. With their backs turned toward the rails, they're holding their cell phones in position and standing arm in arm on the platform at the Üsküdar train station. As the İstanbul Banliyö Trenleri, a commuter train with red and blue stripes, pulls into the station, they snap a picture. A few minutes later it will appear on Facebook with the caption "First time MarmaRay Cool!!!!"

Harun Oruç is also holding his smartphone, but he's not paying attention to the incoming train. He's reading his e-mails. When the doors of the silver train glide open, he looks up and steps into the fully occupied car. Oruç, a 32-year-old patent lawyer, commutes almost daily from Asia to Europe and back again. His office is located on the eastern side of the strait, and some of his clients are on the western side. "It used to take me at least an hour to get from one side to the other," he says. "There were only two ways to cross the Bosporus: the ferry or the bridges. You get stuck in traffic even on the way to the ferry, and the three bridges are permanently congested." Oruç, who would often arrive for his appointments stressed out and with his suit wrinkled, says, "I used to really feel that I was traveling from one continent to another. Today I step into the train in Asia and — zip! — five minutes later I'm in Europe. Fantastic!"

Earthquake-Proof Tunnel. About 15 million people live in Istanbul, a 2,600-year-old metropolis that straddles the Orient and the Occident. About a third of them travel across the Bosporus every day for work or other reasons. Since October 29, 2013, they have had an alternative: the Marmaray Tunnel, which was opened just in time for the 90th anniversary of the Republic of Turkey. The government terms it "the tunnel of the century," and newspapers call it "the new Silk Road of the 21st century" or even "China's nonstop connection with Western European markets." The name of this commuter route, which will be the heart of a future network of long-distance and freight routes, combines the words "Marmara" and "ray," the Turkish word for "rails."

Already some 160 years ago, sultans were dreaming of a tunnel under the Sea of Marmara. But engineering could not cope with the special challenges of the Bosporus until the early 21st century. Not only is the strait characterized by powerful currents that run in opposite directions deep under the water's surface, but the seafloor is at risk of earthquakes. As a result, the underground tunnel had to be built to withstand earthquakes with a Richter magnitude of nine.

What is more, shortly after construction work began, the Roman Empire struck back — with ships, anchors, leather sandals, hairbrushes, and candleholders. Archaeologists found thousands of objects that they identified as relics of Constantinople. The skeletons they excavated are even regarded as evidence that people lived in Istanbul over 8,000 years ago. These discoveries delayed construction work for years.



Engineer Javier Raposo and his colleagues from Siemens Rail Automation in Istanbul thus had to work very quickly during the final phase of construction. They had to make sure that the system, in which commuter trains would glide through the undersea tunnel at two-minute intervals, would enter service in time for the 90th anniversary of the Republic of Turkey.

Today, some 75,000 people are transported every hour in both directions when the system is working at full capacity. That adds up to a million passengers per day — one fifth of Istanbul's total daily traffic.

The Siemens team was able to install the complete signaling and control technology, ranging from individual transmission cables to a complex operating system, only after the tunnel was completed and the rails had been laid. "The timeframe kept shrinking," Raposo recalls. Six months were initially planned for construction of the 13-kilometer stretch between the Kazlıçeşme and Ayrilikçeşme stations, but ultimately that period was reduced to only two months. "That was a challenge, but we met it successfully," he says.

Prefabricated concrete segments (left) accelerated construction of the Marmaray tunnel.

Moving-Block System. The short intervals between trains are made possible by a combination of several systems. These systems ensure that everyone involved — the drivers, control center personnel, and the trains themselves — has the same updated information. For this purpose, the trains are connected to the signaling system via radio. A train control system (Trainguard Sirius CBTC) that is installed in the infrastructure as well as in the trains, collects precise information concerning the location of individual cars. When a train travels through the tunnel, it passes one virtual block after another and continuously reports its position via radio to the block processors, which are connected with the electronic interlockings. The trains then receive instructions telling them how fast they can travel in which blocks. In this "moving block system," balises — small plates equipped with transmitters and receivers and embedded in the tracks — register a train's position and speed. In parallel, the exact position of every train is transmitted to a control system that monitors the traffic flow and guides it if necessary.

"The crucial feature of our train control system is that it knows what conclusions must be drawn on the basis of the information," Raposo explains. "It always knows how fast each train is traveling, when it stops, and when it starts up again. It knows the positions of the individual trains, and it recalculates the driving speed and braking distance for all the CBTC trains that are on a given route. The driver authorizes the train to run in automatic mode after each stop at a station and supervises the closure of the passenger doors." In this way, every train is automatically adjusted to the speed and position of the others.

But the system can do even more. It can save people's lives. Sensors sound an alarm if the earth quakes or water begins seeping into the tunnel. In such cases, trains automatically stop before entering the 1.4-kilometer section of the tunnel that lies under the seafloor, and the system closes the gates at both ends of the section. "The train control system also knows whether there are still trains in this section," Raposo explains. "The gates close only after all trains have left this critical section."

The train in which Harun Oruç is traveling has now passed the Bosporus, and five minutes later it stops at the Yenikapi station. Before the door opens, Oruç glances at his reflection in the train window and adjusts his suit jacket. As he steps out of the glistening rail car, he says, "There's yet another great aspect of the Marmaray Tunnel. I've traveled from Asia to Europe, and there's not a single wrinkle in my suit." He winks before disappearing into the crowd of passengers.

Sandra Zistl

A $57 Trillion

With few exceptions, spending on infrastructures is declining or stagnating throughout the world. The situation is particularly serious in Europe, which is suffering from a financial and sovereign debt crises. The International Transport Forum reports that investment in transportation infrastructure has been decreasing in western Europe since the 1970s. Investments in this area corresponded to around 1.5 percent of gross domestic product (GDP) in 1975 but totaled only 0.8 percent of GDP in 2009. Moreover, nearly 30 percent of funds are now being used to merely maintain the existing infrastructure.

According to an assessment by the Federation of German Industries, Germany's roads are now 14 percent less modern than they were in the early 1970s. The situation isn't any better elsewhere. The U.S. Department of Transportation reports that 15 percent of the country's roads are in "unacceptable" condition. In the energy sector, the South African grid alone has a maintenance backlog of $4 billion — the equivalent of half of the country's annual investment budget for electricity. In Indonesia, the number of vehicles on the road in Jakarta increased by 22 percent each year between 2005 and 2009, even as more and more roads fell into complete disrepair. And a study by the McKinsey Global Institute has concluded that Latin America would have to invest eight percent of its GDP in infrastructure to reach the level attained by developed East Asian countries.

McKinsey has also calculated that $57 trillion would be needed worldwide between 2013 and 2030 just to expand infrastructure sufficiently to keep up with the expected rate of economic growth. This huge investment would be around 60 percent greater than the total amount invested in the previous 18 years. Historically, around 3.8 percent of GDP has been spent on infrastructure throughout the world each year. In the European Union (EU), by contrast, only 2.6 percent was used for this purpose between 1992 and 2011. "People's perspectives have shifted," says Patrick Mäder, Head of the Insurance segment at consulting firm BearingPoint. "Old age pensions and healthcare have replaced infrastructure investments as the biggest expense items in government budgets."

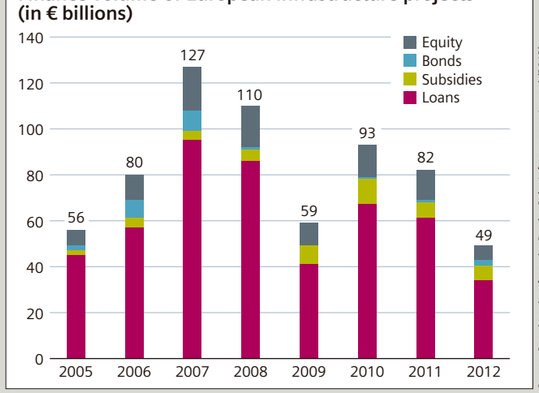
Added to this is the sovereign debt crisis, which has been particularly severe in southern European countries ranging from Greece to Portugal. Spain, for example, cut its budget for public infrastructure expenditures by 16 percent to €9.6 billion for 2013. Back in 2008, the country invested €15 billion in such measures. Some planned projects, such as a high-speed rail link between Madrid and Lisbon, have had to be discarded.

Gap in Infrastructure Investments

The situation is not much better in Germany, even though the country still accounts for 15 percent of all infrastructure investments in the EU. But instead of investing €57 billion in its infrastructure between 2011 and 2015 as originally planned, Germany will probably spend €41.5 billion. At €49 billion, the total investment volume in the EU in 2012 didn't even reach the level of 2005. According to calculations made by BearingPoint, infrastructure expenditures plummeted by €78 billion compared to the record year of 2007 — a decrease of 61 percent. However, this decline is not only the result of tight government budgets. Whereas banks gave private- and public-sector infrastructure investors €95 billion in short and long-term loans in 2007, that figure dropped to €34 billion in 2012. The European Commission is now trying to counteract this development with its Europe 2020 program, which serves as a model for the post-crisis era. According to the European Commission, €2 trillion — about one eighth of annual GDP — should be invested in infrastructure by 2020 to create a "smart, sustainable, and integrative economy." The Commission wants a large part of this investment to be provided by the private sector; but banks, which were by far the biggest providers of loans for infrastructure projects until the financial crisis of 2008, are now much more reluctant to lend, due to tough stipulations that require them to have more equity capital than in the past. The financing gap could theoretically be closed by insurance organizations, such as pension funds and life insurance companies, which would serve as institutional investors. But, according to BearingPoint's Patrick Mäder, regulatory authorities consider long-term infrastructure projects to be as risky as hedge funds, making it impossible for insurance organizations to invest in them. In cooperation with the European Commission, the European Investment Bank (EIB) has therefore created an instrument that makes it easier for institutional investors to form public-private partnerships. The EIB makes a credit check, structures bonds, and sets interest rates. One of the first bonds was earmarked for Castor, an underground natural gas storage system in Spain. Because these bonds have met with a good response, it is hoped the infrastructure sector will soon turn around. *Urs Fitze*

Infrastructure Investments and Loans

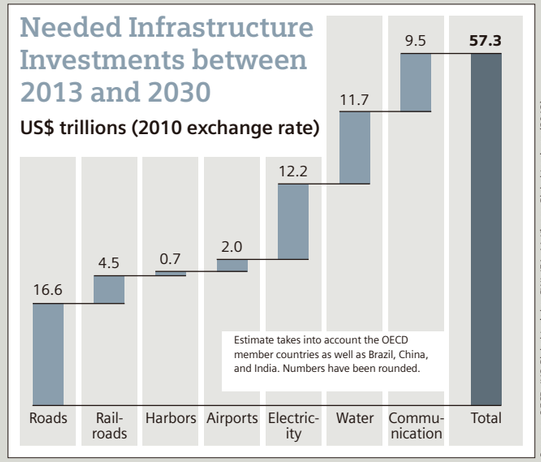
Finance volume of European infrastructure projects (in € billions)



Source: Based on data from the BearingPoint Infrastructure Journal (2013)

Needed Infrastructure Investments between 2013 and 2030

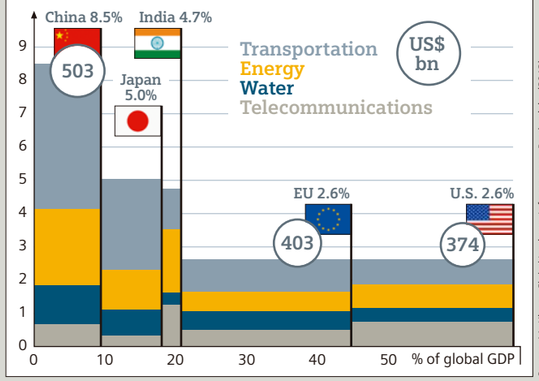
US$ trillions (2010 exchange rate)



Sources: OECD; IHS Global Insight; GWI; IEA, McKinsey Global Institute

Infrastructure Expenditures 1992–2011

as a percentage of respective GDP



Source: Mc Kinsey Global Institute, Infrastructure Productivity (2013)

Condition of Infrastructures

Rank		Rating
1	Switzerland	6.6
2	Hong Kong	6.5
3	Finland	6.5
4	United Arab Emirates	6.4
5	Singapore	6.4
6	France	6.3
7	Iceland	6.3
8	Austria	6.2
9	Netherlands	6.2
10	Germany	6.2
14	Japan	6.0
18	Denmark	5.7
19	U.S.	5.7
23	South Korea	5.6
28	UK	5.4
41	Turkey	5.1
74	China	4.3
85	India	3.9
114	Brazil	3.4

1 = Very underdeveloped — global minimum
7 = Extensive and efficient — global maximum
Many different infrastructures are taken into account: transportation, power, communication etc.

The report evaluates 148 countries on the basis of key indicators (ranging from GDP to child mortality) and a survey of more than 13,000 managers worldwide.

Source: World Economic Forum, Global Competitiveness Report (2013/2014)

Mozambique's infrastructure is being improved so that coal (right) can be shipped to markets.

Railroad to a New Start

Mozambique's untapped reserves of coal are among the world's largest. However, the country was torn by civil war and still lacks an affordable and reliable infrastructure for extracting raw materials. Siemens is helping with a variety of equipment for automation and electrification.

Even today, the inhabitants of Mozambique greet each other with raised hands and open palms. This is a sign that they are friendly and carry no weapons. The civil war has not been forgotten, even though more than 20 years have passed. The bloody conflict between the government and the opposition party that took place from 1977 to 1992 has left traces throughout the country, in the green coastal regions, the barren dry savannahs, and the sprawling inland hills. Many roads and railway lines were rendered impassable, irrigation systems destroyed, and administration buildings turned to ruins.

Since 1992, a variety of projects have been launched to rebuild the infrastructure. Investment is mostly being provided by companies, because the country still lacks the necessary financial resources. "Mozambique's transportation infrastructures are in deplorable condition in some places," says Jesús Guzmán, Head of Siemens Rail Automation in Spain. Siemens has been receiving contracts to improve Mozambique's infrastructure since 2006. For instance, the Mobility and Logistics division is delivering and installing the signal and control systems for a 912-kilometer rail link between the port city of Nacala and the country's interior. And the Low and Medium Voltage division is responsible for the power supply in the local harbor. The customer for these projects is a joint venture of the largest Brazilian mining company and Mozambique's state railway company. Both contracts are part of a major project known as the Nacala Corridor. The project's goal is to build up and expand the infrastructure from the coast to the small town of Moatize in the mountains of Tete province. Plans call for roads, stretches for freight traffic, an airport, and a seaport to be built by the beginning of 2016.

Why Tete? The province is literally a gold mine for coal. According to Germany Trade & Invest, a foreign trade organization, there are 23 billion tons of coking coal here — some of the world's largest untapped reserves. By 2020, production here is expected to reach 100 million tons per year. The coal in Mozambique is especially valuable, as it lies just below the surface. As a result, mining and processing costs are low. "The coal industry is a critical engine of economic growth in Mozambique," explains Rui Marques, Head of Siemens in Mozambique. Largely thanks to this raw material the economy is now booming in this southeast African nation. The gross domestic product here rose by seven percent in 2013, and 8.5 percent growth is forecast for both 2014 and 2015.

Siemens has been involved in the expansion of the infrastructure since 2006. Its latest project is to equip the railway line from Nacala to Moatize with signal and control systems. At 912 kilometers, it is East Africa's longest rail stretch dedicated to freight traffic. The line begins and ends in Mozambique, but between these points more than 200 kilometers of track pass through Malawi. Starting in 2015, plans call for this line to handle coal transportation from the mine in Moatize to a shipping facility in Nacala.

Siemens is delivering and installing various control and signal systems so that coal transport can be organized with maximum efficiency and safety. At the heart of this system is Siemens' Positive Train Control (PTC) system for traffic monitoring and traffic control. "PTC is an efficient signaling solution," says Guzmán. Each train will have a console that will be securely connected with the control center in Nacala via a microwave radio network. All of the information about the individual trains, their trip data, and positions on the line will be collected in the control center in real time and used to continuously update the profile of all line segments. "The control center will be the brain of the entire railway line," says Guzmán.

A display panel will provide train operators with information, and a profile of the railway line will gives an overview of curves and gradients. An animated graphic will provide an image of the train's position in real time and enable the operator to monitor the behavior of other trains on the line.

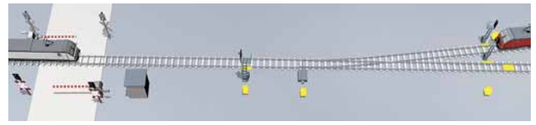
The panels will also display alarm messages. In addition, the system will automatically calculate and display a speed profile, which helps the operator to maintain ideal distances between trains. As a result, there can be more trips in a given timeframe and they can be scheduled more efficiently. All of this is expected to maximize the capacity of the network. Signal boxes will be automatically monitored and controlled, thus reducing the risk of accidents. To begin with, 92 locomotives and 2,328 railcars will be in service, transporting some 18 million tons of coal per year to Nacala. "This project is a wonderful opportunity for us to increase our presence in the African rail industry," says Guzmán.

E-Houses for the Harbor. Once coal is transported to Nacala it will be shipped to ports all over the world. Plans call for this to take place at a harbor built several hundred meters from shore, where the water is around 60 meters deep. This facility is expected to enter service in early 2015. The advantage of this deepwater harbor is that ships of the PostPanamax class, which are more than 32.3 meters wide, can also use the facility. But a prerequisite for all of this is that the harbor must be supplied with electricity — a job for Siemens Low and Medium Voltage division. "Our systems will supply the harbor lights and the operational areas as well as the conveyor systems that are used to transport the coal from the railroad lines to the harbor," explains Marc Grieshammer, the sales manager responsible for the project.

Siemens' solution for power distribution consists of a number of components. A transformer substation will feed in power from the public power supply grid and transform it from 110 kilovolts (kV) to the supply voltage of 22 kV in Nacala's harbor area. Five additional 22 kV medium-voltage and low-voltage distribution stations will transmit the power at different voltage levels to supply consumers within the harbor facility. There are also 20 compact stations — small outdoor enclosures that transform the 22 kV input voltage down to 400 volts.

The special feature of this project is related to the way the power will be distributed, explains Project Manager Jose Godinho. The medium-voltage and low-voltage distribution stations are installed in containers — referred to as E-Houses. These have been placed on bases with pillars, so that their cables can easily be led in from below. The largest E-House is 15 meters long, four meters high, and weighs 66 metric tons. The containers are made in Germany and fitted with various switchgear and power distribution equipment before being shipped to their destinations. The E-Houses therefore arrive completely assembled and tested, and can be set up quickly. That means lower construction, installation, and commissioning costs at the site. "E-Houses are 20 percent cheaper than conventional building solutions with substations for power distribution," explains Jean-Philippe Macary, the Portfolio Manager responsible for E-Houses.

Safety and security are an essential part of the E-House concept. A magnetic card system regulates access by authorized personnel, and a camera system records this access. When a switchgear door is opened, the medium-voltage system immediately switches off to ensure the safety of personnel. "The systems have to be protected against environmental influences, especially in locations like Nacala, which combines a tropical climate with sea air and coal dust," says Siemens Project Manager Hermann Bierfelder. To do this, an overpressure is generated in the interior of each E-House. The containers are also treated with a special offshore paint that protects them against the sea air. The infrastructure project in Nacala is a strategic pioneering venture in Africa.



The control center in Nacala will be the nerve center of the entire rail system — where all information comes together.

Experts believe that in coming years deposits of other raw materials, including gold and copper will be developed in Africa. "Electrification solutions are needed to extract these resources," explains Bierfelder — solutions such as those installed by Siemens between Nacala and Moatize. There, the first trains are scheduled to roll in the fall of 2014, at the same time as the scheduled handover of the keys for the energy distribution systems. All of this represents a small step forward from the destruction left by Mozambique's civil war.

■ *Ulrich Kreutzer*

Rewiring Luanda

Thanks to Angola's booming oil production, its capital, Luanda, is growing rapidly. However, blackouts, power theft, and damage to cables because of excessive construction activity are daily occurrences. Siemens has simulated the city's power network in order to discover weak points and open the door to expansion.

Boomtown Luanda. According to official figures, between six and seven million people live in Luanda, the heart of Angola. In reality, however, the figure is probably much higher. Like a magnet, Angola's capital city attracts masses of people from all over the country to the Atlantic coast. All of them want to have a chance to cash in on the country's tremendous oil boom. Every day, two million barrels of crude petroleum are pumped out of fields along the Atlantic coast, allowing Angola to surpass Nigeria as Africa's biggest oil-producing nation (see *Pictures of the Future*, Fall 2013, p. 9).

The dramatic growth of Angola's economy is sweeping a lot of money into the national budget — money that is urgently needed to expand the country's infrastructure. That's because Luanda is permanently on the brink of collapse. "Only 40 to 50 percent of households have electricity. And in the rural slums on the outskirts of the city, where there's a big influx of new arrivals, entire neighborhoods are sprouting up unplanned, so they can't be provided with power," says Helder Adão, President of Luanda's power company, Empresa de Distribuição de Electricidade de Luanda (EDEL). "In addition, we suffer from power theft, frequent blackouts and damage to cables due to construction work. That's why we're talking to Siemens. We hope Siemens can help us increase the stability of the network by means of new methods and technologies."

An initial important step toward network stability has now been made. "Siemens conducted a comprehensive study on behalf of EDEL, and for the first time it created a complete model of Luanda's electric supply network," says André Jorge from Siemens Angola. "In the process, we have not only recorded all the necessary data but also conducted a study of network protection. That's because insufficient network protection can cause massive damage to equipment in case of short circuits. It can also be a threat to the health of people working at control units."

Helder Adão, President of Luanda's power company, wants to improve the city's electricity networks.

Identifying Weak Points. The first item of business at the beginning of the study was to create order from chaos. Jose Damasio from Siemens Portugal was the technical manager responsible for the research work on site. "To date, the network in Luanda has grown chaotically, without any kind of master plan. For example, some parts of the network weren't even documented at headquarters, and some of the data was incomplete or even contradictory. It took us a lot of time to fill all the gaps in the network plans," he says.

The data that was gathered by Damasio, his Portuguese colleagues, and many EDEL employees on site was sent to Erlangen, Germany. There a project group led by Christian Blug from the Smart Grid division of Siemens' Infrastructure & Cities Sector looked at every aspect of Luanda's power supply network. "The city's mid-voltage distribution network has two voltage levels: 60 kV and 15 kV. The 60 kV level is fed by power plants and the overall transmission network. This network supplies the 60/15 kV transformer stations, which are 18 in number. The local network stations are connected to the 15 kV network, which in turn supplies low-voltage consumer devices," he explains.

Experts from Siemens were able to quickly identify the weak points in the network. "In the past there were repeated blackouts that involved unnecessarily long interruptions, unnecessarily big areas without electricity, and in some cases great property damage," explains Blug. "These incidents were triggered by weak points in the maintenance and repair system, but mostly by inadequate network protection." For example, important protective functions such as cable differential protection were either completely nonexistent in places or largely deactivated — probably because construction activity had released the protective relays too often. A properly functioning cable differential protector consists of two protective devices placed at the beginning and end of a cable. Each of these devices transmits its own measurement of the electric current to the other device. If there is a difference between the two values, the connection is switched off by means of a power switch. In the case of Luanda's short circuits, cable sections that did not have functional differential protectors had not been removed from the network because the protective devices had been deactivated. In some cases the results were catastrophic. For example, in the past one transformer station was completely destroyed this way.

Reliable Data. The inadequate network protection concept was systematically analyzed in Erlangen. To do so, Siemens experts used PSS SINCAL, a network calculation program, as well as data recorded in Luanda to create a digital network model. "The model allowed us to calculate the short-circuited currents that can flow in problem cases," says Blug. "We used it to develop a new network protection concept, and we put together a huge overall package."

The package includes many suggestions for improvement, such as ideas about where additional protective relays should be installed and a comprehensive technology transfer package for Angola. Siemens handed over the complete network calculation model to the customer, installed the PSS SINCAL program on site, and trained EDEL employees to use it. "As a result of these steps, EDEL can now update its database itself and have reliable data for its future work," says Blug. Siemens will continue to be involved in Luanda. For example, it plans to complete a new transformer station in early 2014 and has signed a service contract for three other transformer stations.

In the future, it will be crucial for Luanda to forge ahead with the expansion of its infrastructure in order to prevent Angola from having the equivalent of a coronary thrombosis. But only local Angolan authorities can determine whether the technology transfer is a success or not. "The database that was established as part of the network model is already outdated," says Damasio. "EDEL must close this information gap as quickly as it can so that the controlled expansion of the network is possible." That's because 40 MW of new power in the heart of Angola will be just enough to cover its energy needs for eight months. At that point, the city's total power supply will once again have to be increased.

■ *Nils Ehrenberg*

In Brief

Railroads, power plants, and hospitals. Some say that, unfortunately, there often just isn't enough money for investments in infrastructure. Others say that there is plenty of money, but frequently it just doesn't find its way into suitable projects. Siemens Financial Services (SFS) helps to bring beneficial projects together with the needed capital. For example, in London SFS brought in £400 million to support the financing of new trains for the Thameslink rail line. The goal is to significantly increase passenger volume (p. 56). In addition, SFS supports energy suppliers with financing and helps hospitals to purchase medical equipment through leasing programs, for example in China (p. 60).

From the Orient to the Western world in five minutes. The new Marmaray Tunnel in Istanbul demonstrates how investments in infrastructure can make everyday life easier. Every day local trains carry up to a million passengers through this earthquake-proof tunnel (p. 62).

Only about half of the households in the Angolan city of Luanda are connected to the electrical grid. Before the city's energy supply system can be expanded, Siemens is simulating the city's entire power network in order to reveal weaknesses and discover potential for optimization (p. 68).

The future of the energy supply is also a crucial topic in the Fiji Islands. There, after thirty years of hydroelectric power generation, four large transformers have been replaced with modern high-efficiency units. So far, hydroelectric power has saved the islanders $800 million worth of oil (p. 56).

The state of the entire urban infrastructure of Ho Chi Minh City in Vietnam is being examined. A Siemens study reveals that substantial investments are needed to meet the challenges of urbanization and traffic growth (p. 53).

One of the world's largest coal reserves is "slumbering" in Mozambique. One prerequisite for the efficient development of this resource is the construction of a new rail line to the harbor. Siemens is outfitting this link with signal and control technology and is also responsible for the harbor's power distribution facilities (p. 66).

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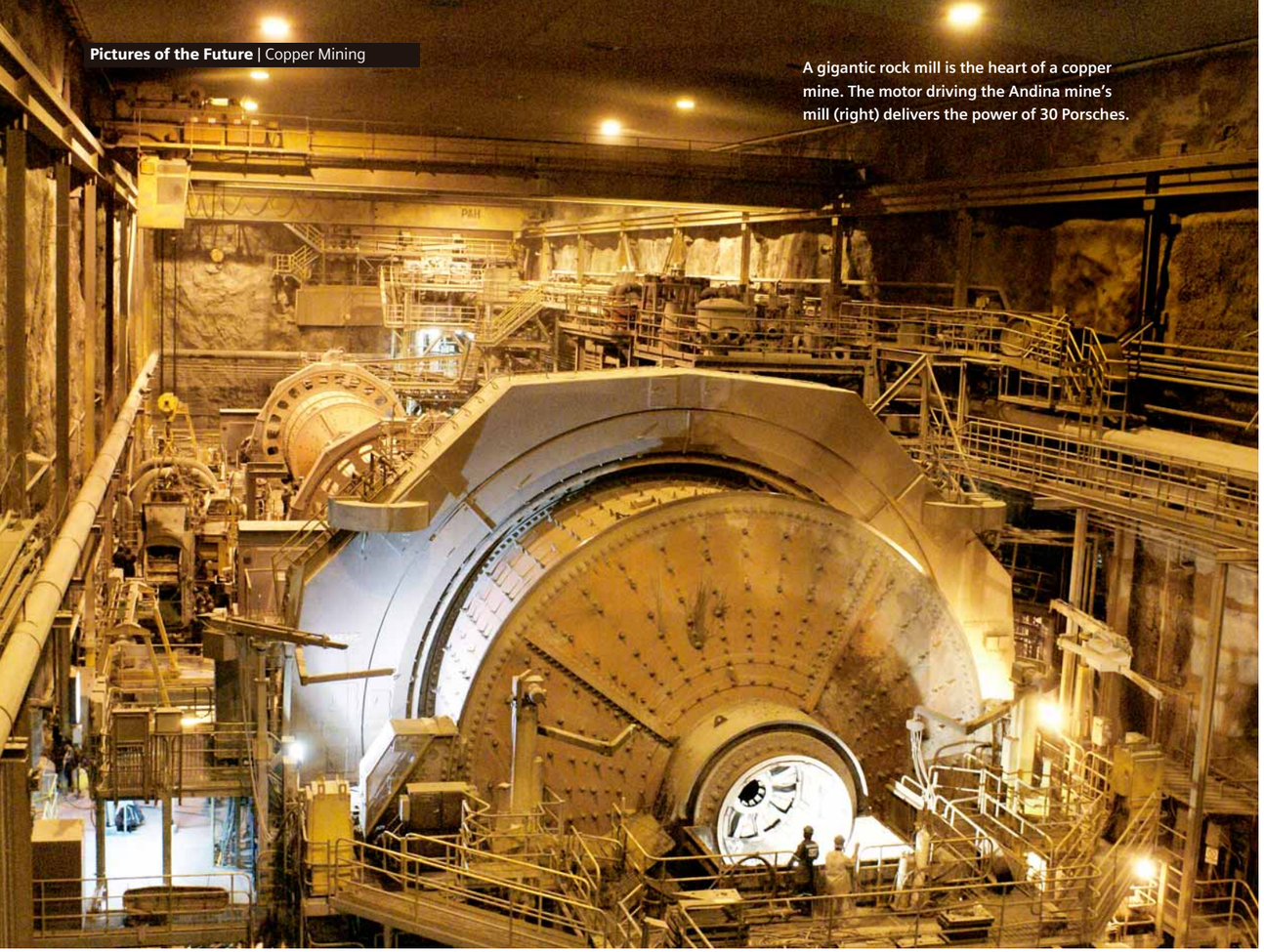


A gigantic rock mill is the heart of a copper mine. The motor driving the Andina mine's mill (right) delivers the power of 30 Porsches.

Treasure of the Chilean Andes

Copper has brought prosperity to Chile. But now the country would like to make itself less dependent on mining by increasing entrepreneurial activity and improving education. Siemens and the "Siemens Stiftung" foundation are helping.

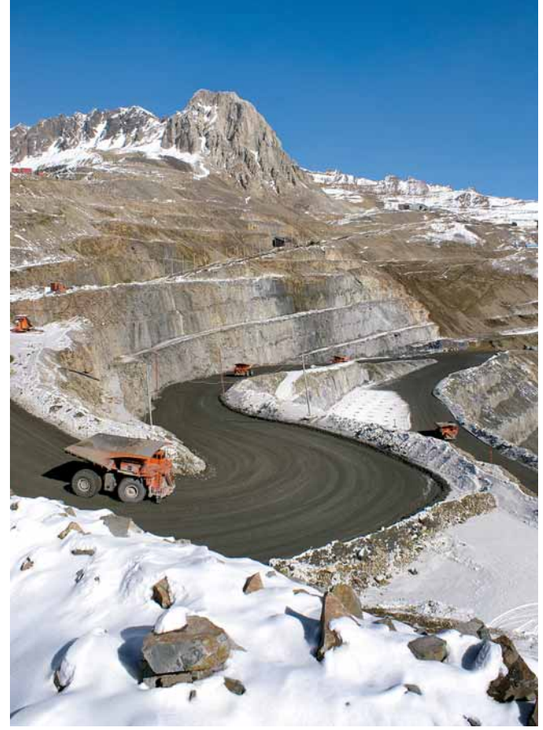
The road to the mine leads through a gorge. Steep cliffs rise up on both sides, and waterfalls thunder almost vertically into the depths. As Isaías Tapia climbs out of his Jeep, his breath condenses into small clouds in the cool air. He has arrived at the Andina mine, more than 2,000 meters above sea level. Snowflakes are falling. Bushes stick out here and there between the boulders. The Chilean Andes are a barren region, not only in winter.

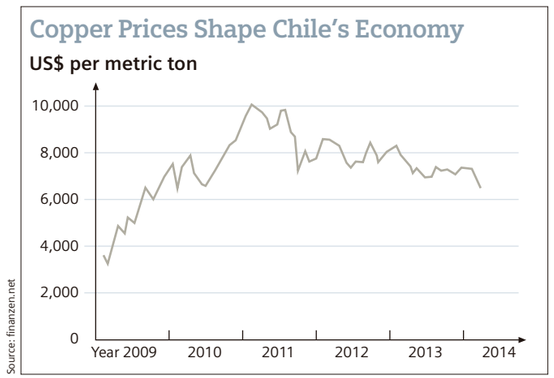
Tapia looks up at the sky. The snowfall is growing thicker. "If it goes on like this, they're going to close the road this afternoon. After that we won't be able to drive down into the valley for a while," he says. Tapia, who works for Siemens, delivers safety equipment and spare parts for Siemens motors to the most remote galleries of the mine, deep inside the mountain. The mountain protects a treasure. More precisely, the mountain itself is a treasure: Almost one percent of its rock is made up of copper. And the world needs copper. Almost every cable and every electrical device contains this metal, and high-quality pipes and fittings are made of it as well. A large part of Chile's copper production is shipped via the Pacific Ocean. China apparently can't get enough of it. About 40 percent of the world's copper production is used there for new apartments, factories, mobile phones, and much more. Between 2008 and 2010 the price of copper increased threefold, before dropping again to approximately $6,500 per metric ton. Chile, the world's most important copper producer, is one of the big winners of price increases. It has the world's largest copper reserves by far, and thanks to its copper revenue it has the highest per capita income in all of Latin America.

Copper has brought jobs with it, and one of the many individuals who have benefited from that is Isaías Tapia.

"I used to work in a restaurant, but Siemens offered me a job I found more interesting," says Tapia, as he walks into the gallery that leads deep into the interior of the mountain. "Now it's my job to ensure that the mine never runs out of spare parts. I also help to make sure that all of the miners go to work with the right equipment, including filters for their mouth protection masks, helmets, and safety jackets." In the mine gallery there's no spring or winter, only the eternal noise of the machines. The noise level can reach 95 decibels, as though we were standing only a meter away from a booming loudspeaker in a disco. "I take care of the ear protectors too," Tapia shouts.

Accident-Free. Siemens has taken over responsibility for maintenance and service at Andina and two other mines from their state-owned operator, Codelco. When all of the equipment is humming along and the mine is operating without a glitch, Siemens receives its payments in full. But if something goes wrong, payments are reduced. Reliability is tremendously important to Codelco because daily losses could easily exceed a million US dollars, should the mine come to a standstill. Almost 2,000 Siemens employees now work in Chilean mines.





If the mine were to stop running, losses could easily exceed one million dollars per day

Tapia is one of them. He's a quiet man who only speaks when it's absolutely necessary. And it's no coincidence that he's doing this particular job. "We need levelheaded workers in the mines — people who are not merely lured in by above-average salaries but who really enjoy working in here," says María José Ponce, a psychologist who works in the Siemens human resources department in Chile. "Anyone who loses his head when there's a crisis down there is a risk to himself and his coworkers." As a result of the economic boom, it's becoming increasingly difficult to find the right kind of personnel and mine operators are groaning about the growing cost of labor. In northern Chile, for instance, the drivers of special trucks receive a bonus that can raise their annual income to $80,000 and more. There, in the Atacama Desert, the excavators in the strip mines are removing the copper-rich ore layer by layer. By contrast, the Andina mine is a labyrinth of galleries that were dug ever deeper into the mountain over decades. Some of the workers affectionately call the mine a *planta con alma* — a factory with a soul.

"If the mine has a soul, it also has to have a heart. And that is definitely the rock grinding mill," explains Aníbal Iannuzi, the 24-year-old Siemens engineer who is responsible for accident prevention in the mine. The cavern in which the mill is located is as spacious as the interior of a cathedral. The entire hall vibrates, and clouds of steam waft through the stale air. The rock grinding mill itself is as big as a one-family house. "It's basically similar to a gigantic washing machine drum that is constantly turning. But it's loaded with boulders instead of laundry. Inside, steel spheres crush chunks of rock that contain copper," Iannuzi explains. The friction generates heat, so the mill is constantly supplied with cooling water, which quickly turns into steam. The crushed rock finally rolls onto a conveyor belt and is transported to a chemical processing area. The mill is driven by a Siemens motor that delivers more power than 30 Porsches, while a Siemens Simatic panel provides an overview of numerous parameters. "All of the rock we extract in the mine has to go through this mill," Iannuzi explains. "If the mill should ever come to a standstill, the whole mine would have to stop operating just a few hours later. It's absolutely essential to prevent any failures. And that's what Siemens takes responsibility for."

Married to Copper. For the mine operators — and the whole country — the formula seems simple. While the mill is turning, money flows into the till. But this works only as long as high prices are paid for copper. That's because about half of Chile's export income comes from copper. "Chile is married to copper," says 39-year-old Pablo Schaeffer, who served until 2013, as Vice President responsible for sustainability at Codelco. At the headquarters of this state-owned copper producer in Santiago de Chile, the door handles are made of copper, the elevators are lined with copper, and copper artworks decorate the corridors.

"Codelco's business model is designed in terms of decades. As a result, partners who are committed to Codelco for a long period of time, like Siemens, are important," says Schaeffer as he adjusts his designer glasses. Codelco is planning investments of $6.8 billion, which would triple its output by 2021. Andina would then be the largest copper mine in the world. This expansion will not involve digging more tunnels — instead, increased use of surface mining is planned.

Chile's copper deposits will last for at least a century, and new deposits are constantly being discovered. However, this metal, which is helping to make Chile prosperous, is also controversial. "Many Chileans want to have the advantages of copper production but not the disadvantages," says Schaeffer. Demonstrations that have been held on the streets of Santiago de Chile reflect these contradictions. On the one hand, students are protesting in order to gain a free education, which of course would largely have to be financed with the revenue from copper mining. On the other hand, citizens are protesting against the expansion of the Andina mine because they fear groundwater pollution.

"These protests reveal one thing above all. the fact that large companies have to talk to people about their plans. After all, development doesn't just mean increasing production in the mining industry and boosting gross domestic product," says Schaeffer, who is now working as a mediator between large companies and various groups of stakeholders. For example, in the mining town of Calama in the Atacama Desert, a development project called Calama Plus has hit the road. Its major objective is to make the city of Calama more livable. Codelco, Siemens Stiftung, and others are supporting the project.

"Calama, with approximately 150,000 inhabitants, still looks more like a mining camp than a town," says Schaeffer. Through the Calama Plus project, citizens have been able to contribute their opinions to the urban planning process. Where should they build parks? Where should streets run? The inhabitants often had ideas different from those of the urban planners and politicians involved in the project. However, it proved perfectly possible to implement many of the inhabitants' wishes. At the top of the list is better education.

Codelco's business model is designed in terms of decades, so long-term partners like Siemens are important.

Chilean schoolchildren in the mining city of Calama playfully discover the sciences, such as how to build solar-powered helicopters, by using materials provided by the Siemens Stiftung.

Education and Cooperation. "Getting a good education is one of the most important levers to allow all Chileans to benefit from their country's high economic growth. But good education needs cross-sector cooperation. Money is not always the main barrier. "Trust among partners is the key," says Nathalie von Siemens, Managing Director of the Siemens Stiftung foundation. "That's why Siemens Stiftung is proud to be able to work with prominent partners such as Pontificia Universidad Católica and Fundación Chile in Calama", she adds.

Siemens Stiftung also contributes its "Experimento" international STEM (science, technology, engineering, and mathematics) education program to schools. The program is based on the principle of learning through discovery. Teachers are trained to spark enthusiasm for the sciences by encouraging pupils to conduct a range of experiments themselves.

"STEM education is more than the early training of skilled workers in technical professions. Industrial value creation is directly correlated to a country's wealth and thus ultimately with its social cohesion. Moreover, STEM education conveys the ability to abstract and to deliberate, as well as technical knowledge. All of these are competencies essential for a mature citizen," says von Siemens. Nevertheless, money talks. Miners can earn three or four times as much as teachers. As a result, too few people want to work in public schools. Parents who can afford it prefer to send their children to private schools. In addition, almost all universities charge high tuition fees.

"The problem is a long-term one, and it is also related to copper. Mining is attracting many of the talented young people and much of the resources, and it's driving up the cost of labor. There is a lack of well-trained workers in the other sectors, in the services industry, and in manufacturing," says Ulrike Wahl, an external consultant to Siemens Stiftung. "As a result, it's difficult for new industrial sectors to gain a foothold. If Chile does not succeed in diversifying its economy and building up other industries, it risks becoming an economic monoculture. Because so much depends on copper, a drop in its price would have severe economic consequences."

Plastic Tubs and Aluminum Foil. Susana Correa Muñoz, the head teacher of the Colegio República de Bolivia in Calama, in northern Chile, agrees completely. "Experimento" has become part of science classes at her school. Fundación Chile and Siemens Stiftung jointly started teacher training sessions by distributing learning boxes, called Experimento kits. Their contents include modeling clay, plastic cups, aluminum foil, and a number of other household items. Astonishing experiments can be carried out with these materials.

In the schoolyard, 11year-old-pupils are now puttering around with solar-powered helicopters they've built themselves. A boy named Matías is putting a cardboard roof on his solar carousel, and a group of girls is admiring the paper ballerinas they have made, which are equipped with solar cells that enable them to make pirouettes. A short while later, dressed in their white lab coats, the class's 45 children are back in the school lab, where the whole story is explained to them: the sun, transformation of energy, an electrical circuit. Matías is enthusiastic. "Before, the teacher would explain everything to us from start to finish, and we only listened. Today we do a lot more ourselves," he says. From Correa's perspective as well, the experiment has been successful. "In the beginning, the teachers were skeptical. We were a bit afraid to open the Experimento kits, as though they were a Pandora's box. But then we realized that we simply had to give the children some leeway. They started to learn and make discoveries on their own. Now we actually just give them advice," she explains.

Chilecon Valley. Who knows? If the students' joy of discovery continues, in 15 years or so Matías and his friends may be knocking on the door at ProChile, a state-sponsored investment agency designed to smooth the paths of young entrepreneurs so that Chilean startups can become internationally successful companies. "In Chile we still have some way to go in fostering human resources for innovations," says Carlos Honorato, the Director of ProChile. "That's why we have to take good care of budding entrepreneurs. We're also attracting entrepreneurs to our country from abroad." In Chile, an individual who has a good business idea is able to establish a company online in just 24 hours. The term "Chilecon Valley" is now making the rounds — half-jokingly, of course.

Nonetheless, high technologies are gradually establishing themselves as elements in the Chilean value chain. For example, Chile's biggest wind farm is being built in El Arrayán, with turbines from Siemens. And the world's largest radio telescope observatory was built in the Atacama Desert. (p.109). Siemens technology is helping to secure its energy supply. Calama and the Colegio República de Bolivia are only a two-hour drive away. Perhaps the engineers of tomorrow are already being shaped there, in the middle of the desert. In fact, the pupils in their white lab coats simply can't get enough of the experiments that are making their school days more varied. Matías is just starting up his solar carousel once again in the schoolyard. Who knows? Maybe one day he too will establish his own technology startup. But when he's asked what he wants to be when he grows up, he answers, quick as a shot, "I want to work in the mine and dig up copper, like my father." ■ *Andreas Kleinschmidt*

Siemens Technologies in Chile's Copper Mines

Even high-quality copper ore contains only a few percent of pure copper. Before that copper can be extracted, heavy rock must first be crushed and transported. A great deal of energy is needed in order to drive these processes. Efficient motors help to minimize the effort and lower operating costs — after all, the price of industrial electricity in Chile is among the highest in the world. In the Andina mine, for example, a rock grinding mill is operated by an energy-efficient Siemens motor. In the Los Pelambres mine, Siemens motors even generate electricity. The copper-bearing rock must be transported over a distance of 13 kilometers from the excavation sites to the processing plant, which lies about 1,600 meters lower — 10,000 metric tons of ore per hour. When the conveyor belt is fully loaded it practically runs by itself, thanks to gravity pulling the rock downwards. The installed Siemens motors use the excess energy to produce electricity. In one year, they can generate almost 100 million kilowatt hours of electricity (see *Pictures of the Future*, Fall 2008, p.17).

Siemens technology is already being used in copper strip mining, for example in the large trucks that transport up to 350 metric tons of rock in a single load. In the high-altitude mines in the Andes, the air is thin. Because of the air's low oxygen content, the trucks' combustion engines operate less efficiently there. To solve this problem, some of the trucks have been equipped with diesel-electric drives from Siemens. The diesel engines can thus always operate at optimal efficiency and temporarily store energy in batteries. The truck wheels are run by single-wheel electric motors from Siemens. This reduces pollutant emissions and energy demand — and saves money for mine operators. In addition, trucks with pantographs from Siemens are used in Chile. Like streetcars, they are provided with energy by a catenary line rather than by an engine. The result is a considerable increase in efficiency and a contribution to environmental protection.

Processes in Chilean copper mines are also being optimized with Siemens' help. For instance, Siemens software is used to control the excavators automatically. In this way, the most energy-efficient path of the excavator shovels is automatically determined. Incidentally, Siemens itself is Germany's biggest consumer of copper. The metal is used by the ton in numerous Siemens products. A large transformer can contain up to 100 metric tons of the material. *Andreas Kleinschmidt*

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Second Life

Former patient Ambrose Turner begins to understand how he has been given a second chance at life as cardiologist Sheila Shelby downloads his "file" and explains the chain of events that allowed him to survive 40 years in an induced coma while the world's population was decimated.

2060 **This is the sequel** to the story of Ambrose Turner, who was introduced in our Spring 2013 issue (see "Underground Economy," page 10). In this episode, following a terrifying encounter with a bionic wolf, the protagonist re-awakens in the hospital in which he spent the last 40 years in an induced coma. His cardiologist, the enticing Dr. Sheila Shelby, explains the technologies that originally brought him back to life, and where all the people have gone...

To call this déjà vu would be an understatement. It was only a few days ago that I was released from this place — a hospital like none I'd ever seen before. But then again, what do I know about hospitals? The last time I even read about one was at least 40 years ago — before the accident in 2020; before the driverless truck that had spun out of control on an icy curve, slamming into my self-driving car; before the dashboard had exploded my vehicle's airbags and crushed my chest; before the lights had gone out. For 40 years I had clung to life by a thread. Then, after treatments that would never have been possible in 2020, after rehabilitation and re-socialization and re-everything else, I was released. I was gliding along the empty roads of Scotland with my old office pal Zeppy, walking across the rolling meadows under which our plant was humming, until, noticing a movement from the corner of an eye, I had looked up and seen a large gray wolf not ten feet from us, its alien intelligence focused on my face. "Only a bionic security system..." Zeppy had cautioned. But the shock had been too much for me...

When I opened my eyes the light was low. A hospital, I thought. Hadn't I been here just a few days ago? Or had another 40 years somehow skipped by? Had I been seriously injured? But I noticed that this time there were no tubes, just a diagnostic sensor bracelet blinking in the soothing light.

"Mr. Turner," a velvet voice spoke into my ear. I rolled over. "Good afternoon," she said. "We were rather worried about you. You were rushed here by ambulance after a bad fall. You had lost consciousness. Those dreadful bionic security creatures! We should have warned you. Fortunately, this one recognized you at the last instant thanks to a biometric cross-check with our release files. But if it hadn't — I don't want to even think…After it realized who you were, it sent us a message expressing its regret. Can you imagine! Well, anyway, I see you've weathered your first shock to our brave new world rather well. Oh sorry, I'm Dr. Sheila Shelby," she said, offering me her hand. "I was your cardiologist during key parts of your regeneration phase. But unfortunately I was called away to another center just before you were reanimated."

Regenerated. Reanimated. Until that moment, I hadn't given my therapy much thought. In fact, to be honest, I hadn't really wanted to know. But this Dr. Shelby…my goodness, I thought as I gave her a long look, she could get me interested in anything! "Would you care to learn about your treatment?" She asked, as if reading my mind. "Oh, by all means!" I responded, realizing that I was feeling better already.

Moments later we were standing at a treatment table that, with its arachnid robotic arms, looked like a huge dormant insect. Each extremity was outfitted with needle-like attachments. "I'll have your file downloaded in an instant," said Dr. Shelby as she touched a screen that had materialized in mid air. And indeed, less than a second later I was looking down at a body that appeared in every way to be mine. "Are you sure you'll be O.K., Ambrose?" she asked, her velvet voice resonating with genuine empathy. "Oh, fine," I lied. "So this is what you call my file, is it?"

"It is indeed. If need be, we could reconstruct any moment along your last 40 years in its entirety. It is a comprehensive, totally integrated record — a learning record, complete with condition and maintenance data on all the systems involved. It is constantly being compared with other files around the world. Such files are of great value to pharmaceutical and robotic systems suppliers, insurance companies, and the worldwide optimization network — the quantum heir, several generations on, of what they used to call the Internet."

"You didn't mention universities or doctors," I said. "Aren't they benefitting from all this?" "It's a long story," she said. "I'll try to explain. You've probably wondered why you were held in an induced coma for such a long time," she went on. "It was not just that your heart and several other organs had sustained a major trauma, but that when emergency personnel arrived at the scene of the accident — given the fact that one of the doors had been blown off your vehicle — they performed a recently-mandated multispectral test to ensure that pathogenic organisms hadn't invaded your wounds. But what the medics found — and it must have been a bone-chilling discovery considering that one of them died only a week later of untreatable lung clots — were traces of a new hypervirulent fungus known as *C. gattii,* a member of the *Cryptococcus* family that actually thrives on humans' high body temperature. Nothing of the kind had been identified before. The fungus may have been deposited by a rodent. At any rate, it represented a potential health care emergency. You were taken to a biosafety level 4 facility. A team of specialists

She moved an icon that fast-forwarded my "case" through many years.

managed to stabilize your condition. But the authorities ordered the facility to put you into an induced coma pending discovery of a treatment for the fungus."

"And if took 40 years to find an answer?" I asked. "At the time, the World Health Organization had no fungal infection program and the drugs that were available produced such toxic side effects that no one in your condition could have survived them," she said. "Besides, very few other people were affected by the condition for a long time. But then, about ten years ago, cases similar to yours started popping up all over. The fungus spread like an aerosol. Warmer temperatures, dry conditions and high winds carried it nearly everywhere. Now you have some idea why the roads are so empty. Our cities, universities and hospitals are no different."

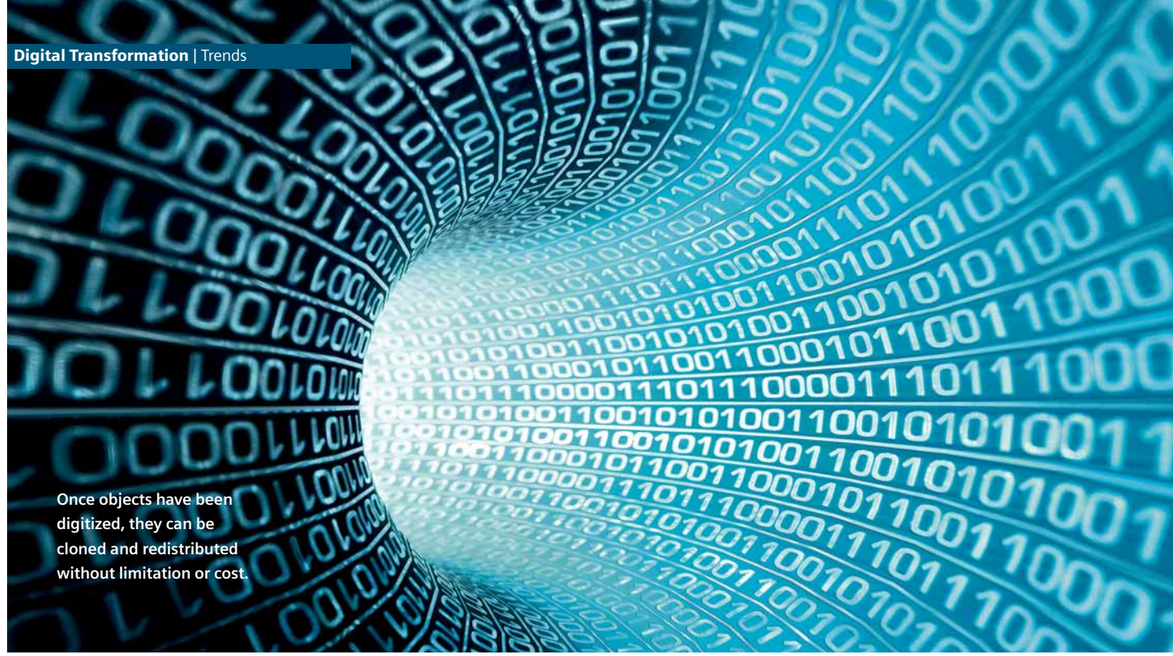
"Why didn't I die of the fungus?" I asked. "The key to overcoming the fungus turned out to be inside your body and those of a few other lucky survivors, myself included. It's a minor genetic anomaly that produces an enzyme that interferes with the fungus's ability to reproduce. Eventually, someone came up with a vaccine and the epidemic was brought to an end. But as you can see, there aren't many of us left."

"Might I have been reanimated long before?" I asked. "No, Ambrose," she said, shaking her head and reaching out to put her hand reassuringly on my shoulder. "No team of doctors could have saved you until fairly recently," she answered. "What you needed were new organs, particularly a new heart. But no one was going to operate on you as long as there was a risk that they might be exposed to your latent fungal infection. And when they finally recognized your genetic anomaly, it became clear that almost any donated organ might have been lethal for you. What you needed were regenerated organs based on your own DNA. And that's what you have now. But there was no technology for creating such organs until recently. Here, let me show you how it worked."

Dr. Shelby reached for the control panel and moved an icon along a line that appeared to fast-forward my "case" through many years. As she did so, the lines on the face of the man on the treatment table grew deeper and the skin softer. Within seconds, the young man had turned into an old one.

"Our robotic systems downloaded cellular-level, multi-modality scans of your damaged organs" said Dr. Shelby. "The scans were integrated, creating what is — for the robots — a transparent patient. Using multi-jointed needles, they aspirated the damaged parts of several of your organs, produced in vivo scaffolding for the replacement structures within your body, and then colonized the scaffoldings with your own stem cells. Decades ago I believe they called this 3-D printing. As you can see, it has come a long way since then. The process is remarkably quick and of course absolutely antiseptic. In the course of the procedure, the robots perform simulations of hemodynamics, pressure gradients, and electrical signaling to optimize the structures and functions they are in the process of rebuilding. Immediately after the procedure is completed, reanimation begins. I guess you know the rest."

It was almost too much for me to take in. I felt as though I had somehow re-lived the last four decades in only a few minutes, and was now utterly exhausted. "Can you see me back to my room?" I asked. "Of course," said Dr. Shelby. But not much later, as I lay in bed thinking about what I had seen, I heard the blood-curdling howl of a wolf from the half-open window and wondered what the morning would bring. ■ *Arthur F. Pease*



Once objects have been digitized, they can be cloned and redistributed without limitation or cost.

Counterpart Culture

Can thousands of buildings and machines be managed and maintained remotely? Absolutely. It's all part of a vast new technological, economic, and social panorama — one in which nearly every real-world object has a digital counterpart.

From the pages of ancient books and cadastral records to the seemingly endless variety of elements in industrial installations and urban landscapes, more and more components of the tangible world are spawning digital counterparts (see p. 97). As this process gathers steam, it is not only the anatomy of the physical universe that is being duplicated in the digital realm, but its physiology. Thus, we are able not only to call up detailed digital images of, for instance, the configuration of machines on a factory floor, but, thanks to the development of biometrically exact representations of humans, to realistically simulate the safest positions and most ergonomic configurations for workers in such environments (see p. 82).

Similarly, as construction of the new Aspern section of Vienna, Austria evolves (see *Pictures of the Future,* Fall, 2013, p. 17), systems developed by Siemens Corporate Technology (CT) are using images generated by quadrocopter drones to track and document construction over the entire 240-hectare site (see p. 99). Such systems, which automatically compare current with previous data, have also been used extensively to track changes inside factories and to ensure that digital plans are up to date.

Software: Secret Ingredient. What's behind this vast migration of objects and functions to the digital world? The secret ingredient that makes it all possible is, of course, software. The key role played by software in virtually every field of technology is reflected in the fact that 40 percent of Siemens' corporate R&D budget is invested in software development. CT, which concentrates on cross-sector projects and fundamental issues such as architecture evolution and complexity reduction, employs approximately 4,500 programmers and software architects. Companywide, Siemens employs some 17,500 software engineers who focus on projects ranging from simulating the Mars Rover Curiosity to innovative power plant controls, displays for railway optimization, and image and data fusion for operating rooms.

Examples of the key role played by software in our increasingly digital world abound. At a Siemens plant near Nuremberg that produces Simatic programmable logic controllers (PLCs), for instance, Siemens' NX and Teamcenter software systems track the results of some 50 million process steps per day ranging from soldering temperatures to pick-and-place speeds (see p. 92). The resulting information is essential to the plant's 99.9988 percent level of quality. The information is networked with the plant's R&D department to refine existing and planned production lines and their processes.

Given the plant's extremely high level of automation, it is widely seen as an example of a first step toward the forth industrial revolution — in which the real and virtual worlds will draw from each other's experience in order to automatically optimize processes. In view of the plant's reputation for efficiency, it is not surprising to see that it has been a model for other facilities. In Chengdu in southwestern China, for instance, a near duplicate of the German plant is helping to

meet China's appetite for PLCs, which are used to manage everything from automobile production to mining machinery (see p. 94).

Among the countless examples of developments in which the real and virtual worlds are coming together is the production of the world's biggest optical telescope (see p. 110). In order to accelerate development, the manufacturer used Siemens NX software to generate a 3-D simulation of the machine that would produce the telescope's 1.5 meter lens and then integrate the simulated data with production systems. The machine, which has a polishing accuracy of 30 nanometers — was developed in just 1.5 years.

Portable Image Integration in the OR. The digitization of the physical world is also reaching deep into the health care environment. At Siemens Corporate Technology in Princeton, New Jersey, for instance, researchers are working with specialists from Siemens' Healthcare Sector to integrate preoperative 3-D computed tomography and magnetic resonance images with real-time images generated by other modalities in the operating room or interventional suite (see p. 104). The idea is to use the high-resolution 3-D images to provide the navigational landscape in which all other modalities will eventually be integrated.

Nor will multimodality data fusion be limited to images. Researchers foresee the integration of information such as live patient monitoring, and even on-the-spot simulations of some functions into a single, integrated, real-time image that may soon be wireless and portable. Indeed, portability of fused data sets is a key part of the vision. A portable image would support the integration of visual and mental activity with hand-eye coordination and might even be used in an augmented reality context, thus allowing a surgeon to superimpose diagnostic information on his / her actual field of view. In view of the many advantages of portability, Siemens researchers are developing techniques to promote extremely fast visualization, including ways to tailor streaming and video compression to medical applications.

Regardless of whether the subject is industrial or healthcare environments, hardware or software, most advanced systems in our digital world are designed with automated monitoring, preventive maintenance, and remote service in mind. Siemens' common Remote Service Platform (cRSP), for instance, now tracks some 250,000 systems ranging from skyscrapers and gas turbines to the traffic control centers of 255 cities. It also monitors and provides service for about 120,000 high-end medical devices (see p. 84). Collectively, these systems generate some 10 terabytes of data per month. But as the sophistication of monitored systems grows, their diagnostic sensors and software-driven functions proliferate. As a result, experts predict that by 2020, the cRSP will need to handle around 80 terabytes per month. To enhance security and ensure sufficient capacity to manage this avalanche of data, Siemens is developing a next-generation structure.

By consolidating and virtualizing infrastructures and expert knowledge, cloud-based services lower costs.

Software is the key to highly automated production (left) and multi-city traffic management.

New Economics. Even as monitoring and maintenance of an ever-growing population of systems migrates to the digital world, the physical infrastructure with which these functions are associated is itself being digitized. Why, for instance, should each city need its own traffic management center? In Germany, ten cities have basically outsourced this function to a single Siemens service center (see p. 84). Thanks to the availability of all their data via cloud-based Internet services, each of the cities can plan for and manage local events that affect traffic without the need for expensive physical facilities and associated maintenance.

IT infrastructures are also heading for the heavens. So vast are the quantities of data being generated by automated systems that even major companies such as Siemens are being confronted with a growing storage challenge — and the magnetic attraction of the cloud as a virtualized IT solution. With this in mind, Siemens Corporate Technology is supporting the company's business units with an initiative designed to identify new ways of designing products that take advantage of cloud storage without compromising security (see p. 79). By consolidating and virtualizing infrastructures and expert knowledge, cloud-based services lower costs. Indeed, the International Data Corporation (IDC), a market intelligence provider, estimates that the migration of services to the cloud will be the determining factor in making so-called "smart data" economical (see p. 88).

There can be little doubt that the rapidly advancing digitization of products, services, and, above all, knowledge, offers vast potential benefits. One key area in which all of us will feel it will be our relationship with government. Vasilis Koulolias, Director and founding member of Belgium's eGovlab, envisions electronic government as the next step in democracy. "It implies a change toward more intelligent, efficient and representative government; it will reduce the transaction costs of collaboration, co-creation and interaction," he predicts (see p. 100).

But for all its potential, our brave, new digital world should be considered with a measure of caution. As our interview with Prof. Erik Brynjolfssen, Director of the MIT Center for Digital Business, points out (see p. 90), both blue- and white-collar jobs are increasingly in automation's crosshairs. "Digital technologies can be used to create enormous wealth," says Brynjolfssen. "But that wealth can be concentrated in the hands of a small number of people or it can create widespread opportunity for billions of people. We have it within our power to create shared prosperity. But that will never happen if we just close our eyes and assume it's going to happen on its own." ■ *Arthur F. Pease*

Once all technical data is stored in the cloud, service technicians will easily be able to access it from the field.

Broader Horizons for Data Services

The "cloud" isn't simply a virtual place in which we can store data; it's also a force that will change industrial processes and services. Siemens is on its way into the cloud era.

Analysts at market intelligence firm IDC estimate that about 40 zettabytes (a number with 21 zeros) of data will be created, copied, or consumed in 2020. Storing that much data on DVDs would require a pile of disks roughly 30 times the distance from the earth to the moon. This development is being driven by the digital networking of humans and machines — the former in professional and private social networks, the latter in automation systems. In addition, people and machines are also increasingly networking with one another — for example, when service technicians tap into condition monitoring systems in medical scanners or gas turbines.

The resulting flood of data is creating a major challenge for companies, which have to continuously expand their information technology (IT) infrastructures so that they can store and process their data. An alternative to this is cloud computing, which enables companies to cut costs and improve the quality of data processing. "Cloud computing is basically the virtualization and automation of IT. It can also provide high storage and processing capacity on short notice," explains Dr. Birgit Schiemann, who heads a cloud project group at Siemens Corporate Technology (CT). Because her project group is of great strategic significance for Siemens, it has the status of a core technology initiative.

Dr. Schiemann uses office PCs to illustrate where IT development is going. Whereas every employee currently has his or her own hard disk, on which an operating system, programs, and data are stored, in the future, all they will need will be a keyboard and a display device. Everything else will be stored in a digital cloud at a major provider's server farm.

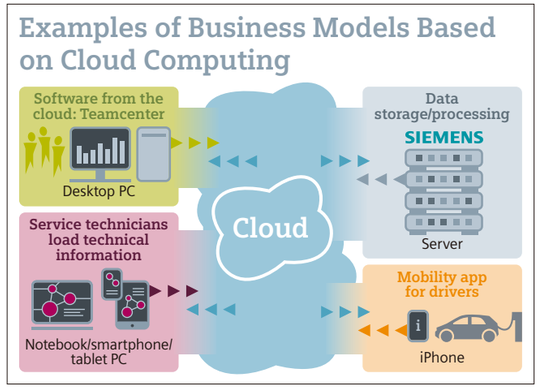
Many workers will access their data only via mobile computing, meaning that a tablet computer will be all they will need. Cloud computing is thus the outsourcing of storage and computing capacity. By far the biggest provider of this service is Amazon, which already years ago created huge server capacities to handle the online shopping rush in the run-up to Christmas. But because much of this capacity wasn't needed during the rest of the year, Amazon began renting it to other companies, and the first cloud computing infrastructure was born.

Security is Central. Cloud computing has triggered a process that ultimately raises the question of whether companies will even need to maintain their own IT infrastructures in the future. Companies must adopt new approaches to dealing with the growing amounts of data that need to be stored and the ever-increasing requirement for computing power. Although cloud computing has the advantage that users don't have to invest in the systems themselves, major technology companies, in particular, were for a long time

skeptical about this service because of security concerns.

"Security continues to be one of the biggest challenges in our project," explains Schiemann. She and her team have to determine what kind of cloud is best suited for each application and solution at Siemens' four sectors. For example, the company has a public cloud, where data is encrypted when it is transmitted between rented servers and users, but the cloud's servers process data from many different clients. However, this is frequently not a suitable solution, largely due to legal constraints. This is particularly true when the data includes personal details, company secrets, or information that is transmitted from one country to another. In many cases, these challenges can be solved with the help of the virtual private cloud, in which the provider ensures that a server is used only by one client.

Cloud service providers can also guarantee that data will not leave a particular country if this is not permitted due to legal reasons or security concerns. "Every business unit has to resolve a wide range of issues before applications can be used in a cloud," says Schiemann. Her team supports such processes not only by providing strategic advice, but also by creating software modules for recurring applications such as model architectures that have proved their technological worth for cloud computing applications, user authentication systems for accessing the cloud from a terminal, and systems for distributing data between different storage locations on the basis of predefined categories.



Cloud computing is changing value chains, and it will therefore change companies as well.

However, the cloud core technology initiative's main aim is to help Siemens' Sectors analyze how cloud computing can provide benefits to products and services. "Cloud computing is changing value chains," explains Schiemann, who predicts that "it will therefore change companies as well."

Billing by Use. On the one hand, this means that product design technology will have to be configured in such a way that it can meet new cloud-based requirements. For example, Siemens' PLM Teamcenter software is available as a cloud-based solution in addition to its standard version. Whereas software has mostly been licensed to date, it will increasingly also be made available through long-term subscriptions or as a pay-per-use application. "This means that software will have to be redesigned," says Schiemann.

When companies no longer have their own storage and processing infrastructures, programs will have to run on devices on which they aren't installed. Consequently, they will have to be conceived in such a way that multiple users can access them at the same time.

On the other hand, it will be possible to develop completely new products that wouldn't be imaginable without cloud computing. Experts in Siemens' Sectors are developing strategies for determining which applications will be migrated into the cloud so that they can be more easily accessed there with a view to offering increased functionality.

Just how wide-ranging the application possibilities are is demonstrated by the Siemens Power Academy, which trains tens of thousands of people each year for new applications in the fields of energy generation, transmission, and distribution. Previously, course participants had to take a package of training materials that weighed several kilograms home with them. This was especially inconvenient for people who traveled by plane. Since 2013, however, all of the training materials for the Instrumentation, Controls & Electrical unit have been made available in a cloud. To make this possible, Timo Wolf from CT developed an app that was installed on iPads owned by Siemens. "During the course, participants use iPads that allow them to access the cloud," explains Detlef Rautmann, founder of the Siemens Power Academy. The app is integrated into the Web server of the Learning Management System, which manages the content of all of Siemens' training courses. During the courses, participants can also enter comments or sketches into the iPads and store them in the associated cloud. When they are back at their workplaces, participants can use their passwords to access their personalized training materials, which they can also download to a PC or other device.

More than Apps. Experts at Siemens are convinced that such digital applications will develop into genuine cyber business models over the next few years. "Siemens won't just develop apps," says Raj Varadarajan, who is helping to shape Siemens' digital transformation from Corporate Technolog's Princeton, New Jersey location. Instead, the aim is to find out where mobile computing — the use of mobile devices to access a central infrastructure that can be supported by a cloud — will be headed in the future. According to Varadarajan, features from social networks will have a big impact on new products. For example, if patients from all over the world discuss the symptoms of an illness, this information can be incorporated into an automated diagnostic tool.

Patient consent is, of course, a prerequisite for such applications. Users could, for example, contribute to the data collected in a diagnostic tool through the information they enter into corresponding patient blogs or other websites with medical content.

At the moment, we can only guess which new applications will arise as a result of the technological possibilities of cloud computing and mobile computing. However, if ideas develop as rapidly as they have with privately used apps, a wide range of new business concepts and models could become available in the near future. Analysts such as those from the IT business consulting firm Gartner say that the market for cloud computing applications is growing much faster than the IT market as a whole. This development is being driven by new IT scenarios that use cloud computing applications and by the transition from traditional IT services to services in clouds — and Siemens is right at its heart.

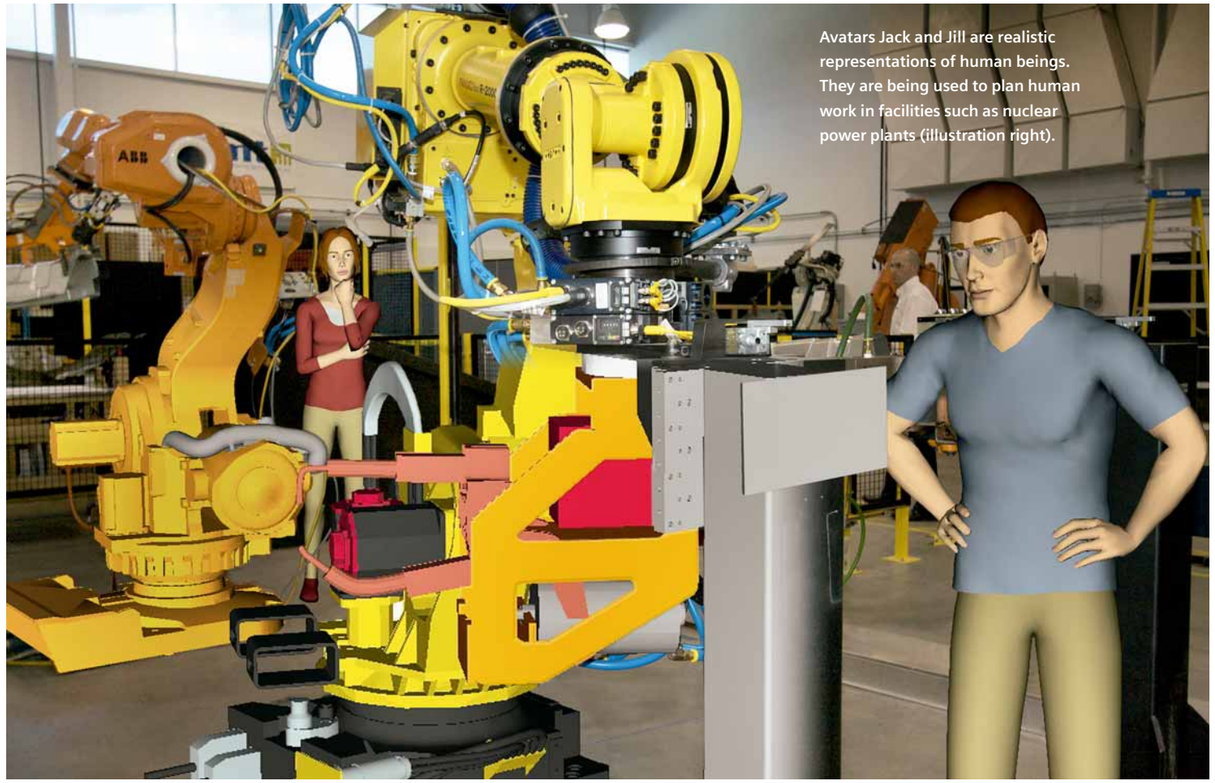
■ *Katrin Nikolaus*

Mobility from the Cloud

Sabine P. is late. She is in Berlin, close to Kurfürstendamm, and has 15 minutes to get to a meeting on Hackescher Markt in the city's downtown area. Although the two locations are only slightly more than seven kilometers apart, it's nearly impossible to quickly cover the distance in this hectic city, even for people who know their way around. Although Sabine is a stranger who comes from Cologne, she is unconcerned, because her smartphone has an app from her mobility services provider — in this case, her favorite carsharing company. No matter in which city Sabine happens to be, the app shows her the quickest way to get to her destination. In addition to incorporating the information about all public and private transportation systems, the app takes the current traffic situation into account. Sabine merely has to touch her phone, and the map on her display shows her where she is. The app gets traffic information from the cloud-based mobility platform, where the data is updated every second. Sabine's display shows the latest information about traffic conditions, parking spaces, taxis, carsharing vehicles, rental bicycles, and the stops and departure times of public transportation systems — in short, all of the mobility services that are available to her. She enters her destination, and the app in the cloud calculates which mode of transportation will bring her there the fastest under current traffic conditions. Three suggestions appear on the display. Sabine selects the first one, which tells her that she should first rent a bicycle. The nearest rental bicycle stand is located 20 meters away. From there, Sabine should cycle to the commuter rail station and take the next train to downtown Berlin. However, if Sabine pedals quickly, she could reach Hackescher Markt in just 20 minutes. Alternatively, she could use a nearby rental car from a carsharing company. However, the app shows that most of the streets to her destination are congested if Sabine takes the quickest route. As a result, it would take her 35 minutes to drive there. She therefore presses a key to rent a bicycle. The unlocking code appears on her smartphone and she rushes to the bicycle stand. The appropriate train ticket is also sent to Sabine's smartphone before she even gets on the bicycle. She can pay for everything through her mobility service provider. The "mobility cloud" enables the invoices to be settled between the various service providers. Everything goes well, and the other participants even arrive five minutes later than she does to the meeting. "Sorry, I was caught in a traffic jam" is their excuse. The mobility services can be easily integrated into existing apps. The services come from a "cloud" that was created by experts at Siemens' Infrastructures & Cities Sector. "Our customers are public transport providers, carsharing companies, regional administrative bodies, and municipalities," explains Steffen Schäfer from the Mobility and Logistics Division, which is developing the platform. As experts were developing and implementing the system, they received help from the Cloud Computing project team at Corporate Technology. The team is drawing up a cross-sector strategy for cloud-based applications and creating the basis for its technical implementation. The platform is one example of how cloud computing is leading to new business models at Siemens. The product is an integrated mobility platform (IMP), and the customers are companies that offer their products (in this case transportation systems) on the platform through their own apps. In fact, some transportation companies have already been operating such apps for years. "Transportation companies and carsharing firms don't need a new app to dock onto the platform. The service is scalable and the companies can easily connect through their partners' mobility cloud back-end systems," explains Schäfer. The advantage for the companies is that the mobility cloud enables service providers to network with one another. "This allows you to use your carsharing app to buy subway tickets, for example," says Schäfer. The platform also has software that handles all of the invoicing for the different companies. In principle, the entire system could also operate on a conventional server. But the advantages of the mobility cloud are obvious, because the amount of traffic and the associated transactions in urban transport are ten times higher during the morning and evening rush hours than during off-peak times. In Germany, traffic levels also jump prior to Christmas and at the beginning of school vacation. At those times, far more people are simultaneously trying to get to the airport or to a train station. Weather conditions, such as the onset of winter, also affect the number of IT transactions that are conducted in order to provide information, make reservations, or generate and pay for travel tickets. Sufficient computing capacity that is otherwise left unused has to be provided at such times. Only cloud computing can ensure such quick scalability. Another benefit is that Siemens focuses solely on the mobility platform. All of the purely IT-related services are bought from specialized companies. "That way we can always use the latest top-quality technology," says Schäfer.

Katrin Nikolaus

A new app from Siemens provides real-time optimized route alternatives, and even tickets that can be downloaded to a smartphone.



Avatars Jack and Jill are realistic representations of human beings. They are being used to plan human work in facilities such as nuclear power plants (illustration right).

Risky Job? Hire an Avatar

Avatars Jack and Jill from Siemens' Tecnomatix portfolio are helping the U.S. energy industry minimize the amount of radiation its employees are exposed to at nuclear facilities. Such virtual test persons are also being used in the automotive and aerospace sectors.

Jack opens a door in a nuclear power plant. Inside the room is a defective pumping unit that forces cooling water through the plant's reactor core. Jack puts his toolbox down on the floor in front of the pump, reaches for a pipe wrench, and begins making repairs. After he turns the wrench several times and removes a cap, the reading on a radiation measuring device begins to rise alarmingly. However, Jack doesn't seem at all concerned by this. A few minutes later, he performs the same task as before while crouching on the other side of the unit. This time, the reading on the measuring device is comfortably located in the safe level.

Jack does all his work in a very relaxed manner — and with good reason, since he is never really in danger. That's because Jack isn't a real person, but rather an avatar, a simulation of a human being. Jack "works" in a virtual nuclear power plant, where he tests the maintenance and repair operations that will later be carried out by real workers.

Such 3-D simulations of work in dangerous areas are designed to lower risks for human beings as much as possible. The simulations help energy companies adhere to the "As Low as Reasonably Achievable" (ALARA) safety principle, which has established itself in the U.S. and, more recently, in the European energy sector as well. "The U.S. energy companies that assisted us with our simulation development work are now testing the avatars in these new applications," says Dr. Ulrich Raschke, Director of Human Simulation Technologies at Siemens Industry Automation in Michigan.

Model People. Jack and his colleague, Jill, are biometrically correct models. Such models have been used since 1997 by engineers and designers in the automotive industry, the military sector, and the aerospace industry to help create ergonomically optimized work environments. They also help in the planning of work processes and in testing the user-friendliness of new products. The simulations created by Siemens are part of the company's Tecnomatix portfolio for industrial production planning. Tecnomatix, in turn, is part of Siemens' Product Lifecycle Management (PLM) software systems.

Jack and Jill are more than just dull graphic figures. They have 68 joints and can perform 135 movements that correspond almost perfectly to the physical movement capabilities of the human body. Both are depicted as average body types common to the population in the regions where they are used. This explains why their Chinese versions are shorter than their North American ones. However, their physiques can also be varied to ensure that very short, tall, thin, or heavy people will later be able to work effectively in the environments depicted in the simulations.

Data from scientific studies is used for analyses that answer such questions as: How much stress will a body be exposed to when lifting heavy objects? The results make it possible to predict the risk of injury and the likelihood of fatigue. A movement program developed jointly by Tecnomatix and the Humosim lab at the University of Michigan "propels" Jack and Jill through virtual factories. An algorithm for calculating radiation levels now makes it relatively easy to use this program to simulate work in a nuclear power facility. The algorithm was provided to Siemens by the Electric Power Research Institute (EPRI), an organization founded by U.S. power companies.

The benefits of virtual testing are obvious. Avatars enable companies to consider the human factor at the earliest stages of product development, assembly, and maintenance planning processes. Instead of building expensive and untested prototypes and making time-consuming and costly adaptations later on, avatars enable engineers to prevent design errors and avoid having to make extensive improvements. This not only saves money; it also improves the quality and safety of products — and speeds up their market launch.

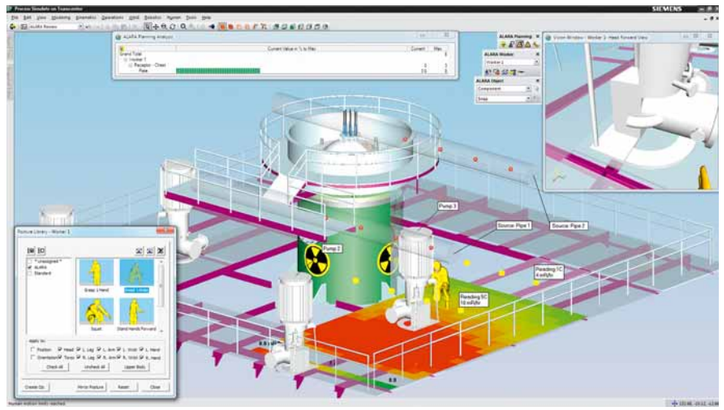
Ergonomic Testing. Ford has been using Jack and Jill since 1998 to test assembly line work areas and vehicle models. Here, the avatars are enhanced by algorithms that calculate postures, movements, and stresses exerted on the body, using data based on years of observations.

Ergonomic analyses are then used to calculate the risk of injury. Development engineers also want to know how well people will steer their vehicles, how easy the instrument panel is to operate, and what view of the road ahead the driver's seat will offer. To find out, they don immersive headsets that allow them to enter the 3-D world of avatars, as in a computer game.

Jack and Jill software from the Tecnomatix portfolio has also proved valuable in actual manufacturing operations. A few years ago, Ford's Ergonomics Lab found out with the help of this software that the installation of door weather stripping in certain models was difficult. Workers were tiring more quickly, their risk of injury had increased, and the stripping was often installed incorrectly.

Avatars enable companies to plan human factors into product development, assembly, and maintenance processes.

After the problem was discovered, Ford engineers improved the stripping installation process for new models. This not only made assembly much easier; it also significantly enhanced quality. "Simulation software can help to substantially reduce manufacturing problems in the automotive industry," says Raschke. "Virtual analyses are now a required step in the design process at Ford and other companies."



Simulations at nuclear plants mark a new area for Tecnomatix. Ultimately, however, they're simply an extension of the simulations in the automotive and aerospace industries. Siemens has been working with EPRI on nuclear facility simulations since September 2010. EPRI researchers developed an algorithm that determines radiation intensity by taking into account the material in question, the radioactive field, and any protective barriers that are present. This means that radiation levels can be precisely predicted for every spot in a room.

Siemens engineers installed the algorithm in the Jack and Jill program. The algorithm allows radiation intensity to be measured with a simulated radiation dose measuring device. The results are color-coded in a 3-D simulation. Here, red stands for dangerously high radiation, while green indicates non-harmful doses (see illustration below).

Siemens also added a Microsoft Kinect motion sensor camera, which is a familiar part of many game consoles. The Kinect records the movements of real people and transfers them to Jack and Jill. This makes it possible to practice exactly how work will be carried out within a nuclear facility before an actual assignment in order to minimize radiation exposure. "If all the radiation sources were known and all the physical structures were stable, it might even be possible to simulate cleanup work in Fukushima," says Raschke.

The technology's potential extends far beyond nuclear power plants or radioactive waste storage facilities, however. Indeed, the earliest simulations of human beings in work environments were carried out in the 1960s and 1970s to study work in space. And in recent years, NASA has used Jack and Jill in simulations for assembling the Orion space capsule. "These days we get a lot of inquiries from both government and private space agencies that want to simulate human activity in space," says Raschke.

Hubertus Breuer

Maintenance engineers can now remotely analyze hundreds of thousands of devices and even the traffic control systems of entire cities.

Minority Report for Machines

Rather than preempting crimes, as in the thriller *Minority Report*, Siemens' common Remote Service Platform is helping to predict and prevent costly breakdowns in machines ranging from turbines to tomographs. The next generation of the platform will be equipped to handle a huge increase in data, thus making new business models possible.

Everything's green in Duisburg. Well, almost. That's because many green dots and only one red one can be seen on a huge display that shows the city's street network. Every dot represents a traffic light. Green means everything is working perfectly; red means the opposite. Bakir Bijedic-Hoffmann, Head of the RCM Support Center in Munich, clicks on the red dot. The display tells him that one of the traffic light's red lamps has burned out. This is not a big problem, because traffic light systems generally have at least two traffic lights for each direction or two light bulbs for the red signal.

However, before the second bulb fails, a technician should replace the burned-out bulb. The computer's database reveals that an elevating platform truck will be needed to accomplish this, since the defective lamp is located in a hanging traffic light several meters above the ground.

In the past, a technician would have driven to the traffic light and inspected it, then driven back to the workshop to get replacement parts or an elevating platform truck. But these days, thanks to the common Remote Service Platform (cRSP), the approximately 380 service technicians who maintain Siemens traffic lights in Germany know what to expect before they even get into a service vehicle. The cRSP is a uniform IT infrastructure consisting of computer centers and data links through which all Siemens Sectors conduct remote maintenance. Traffic computers in cities, motors in power stations, and computer tomographs in hospitals regularly transmit status data through the system to three Siemens computer centers worldwide. In return, the cRSP automatically sends software updates to some of the systems it is hooked up to. Service personnel use the status data to organize maintenance and repair of systems. In some sectors, this is even done in advance before a defect occurs.

At the Support Center in Munich, Bijedic-Hoffmann and his seven employees monitor traffic computers in 255 cities worldwide, from Abu Dhabi to Würzburg. Each year, service technicians handle around 65,000 repair and maintenance jobs in Germany alone. Control centers in Essen and Nuremberg are notified of faults either by customers or automatically by traffic computers. The centers, in turn, notify service technicians by calling them on their smartphones. In most cases, Siemens guarantees that it will have someone on the scene within two hours or will begin eliminating the fault by that time. If a service technician doesn't know how to resolve a problem, he or she calls experts in Munich, who then log into the system through the cRSP in order to find the cause of the fault. As a result, it generally doesn't take long to repair a faulty system, such as a traffic light or a traffic computer.

No Substitute for Service Contracts. Despite the advantages of remote maintenance, some cities still view it skeptically with regard to traffic management. Such cities, perhaps because of data protection concerns, prefer to do everything themselves. "People don't automatically buy remote maintenance," says Klaus Selbach, a product manager for remote maintenance services at Siemens Industry in Nuremberg. Selbach advises operators of large electric motors and transmissions. The breakdown of a motor with an output of over 250 kilowatts can have serious consequences for associated processes, and the cost of the breakdown can far exceed the cost of remote maintenance services. For example, if the drive unit of a power station's coolant pump stops working, the plant will stop generating electricity, which could cost hundreds of thousands of euros in losses each day. Nonetheless, some customers prefer to risk paying breakdown costs rather than investing in a service contract. But that can backfire. Selbach's team knows from experience that service contracts almost always pay off.

On a daily or hourly basis, condition monitoring systems transmit information on the status of motors and transmissions through the cRSP to Siemens maintenance centers. The monitoring systems report the status of motors and transmissions in power stations, mill drives at mines, cement manufacturing plants, and oil and natural gas facilities. They are equipped with temperature and vibration sensors and transmit information on torque and rpm, which reveal how much stress a powertrain is experiencing. If critical levels are exceeded, technicians can study the data in depth and even observe conditions in real time. Imminent faults, such as a worn-out bearing, can thus be discovered before the bearing falls apart in a cloud of smoke. "We've prevented several such breakdowns," says Selbach.

Keeping Medical Equipment Healthy. Predictive maintenance — the inspection and anticipatory repair of systems before they break down — uses technology developed by Siemens' Medical Engineering Group, a pioneer in the area of remote maintenance (see *Pictures of the Future*, Spring 2009, p. 60). Back in 1985 In England, when Siemens equipped a computer tomograph with a modem for remote-distance diagnostics, data was transmitted at only 300 bits per second. Today more than 120,000 medical devices, including magnetic resonance tomographs and ultrasound scanners, are connected to the cRSP, along with 10,000 users. The devices automatically receive software updates of up to 10 gigabytes. In 1985 it would have taken several years to transmit such a huge data packet. cRSP was developed by a network of Siemens Groups. Healthcare is the leading user, accounting for 80 percent of the data volume and functions. All other Siemens units use the same infrastructure of computer centers and transmission logs for their work, but they combine it with their own applications and business models.

From a control center in Munich, Bijedic-Hoffmann's team can track faults in 255 cities worldwide, including traffic lights that need service.

Half a Million Devices by 2020. A total of 250,000 devices are connected to the cRSP — a figure that is expected to double by 2020. The Healthcare Sector alone transmits 10 terabytes of data per month through 20 million connections. Volume is rising dramatically from year to year, and is expected to reach 100 terabytes by 2020, because more and more device functions consist of software, in which faults can be easily eliminated remotely. The data gained in this way also serves as the basis for new business models, which can be developed through business analytics or by studying the correlation between medical and demographic data.

"As the amount of data grows, the cRSP system will reach the limits of its scalability and costs in a few years," says Sascha Sandner, who manages the Remote Services Business at Siemens Healthcare. That's why a new technology is needed — and it's already in the pipeline. The Siemens Healthcare, Infrastructure & Cities, and Energy Sectors have teamed up with Siemens Corporate Technology and Healthcare IT to develop a new system known as cRSP Next Generation. The new system will have a modular design, and its improved architecture will enable it to handle the substantially greater data volume that will be generated in the future. It will also have better security functions and new

possibilities for connecting inexpensive equipment. New, smaller computer centers will be added, and devices will transmit data only to the center that has enough capacity at the moment. Each device contains a communications agent that decides what kind of data is to be transmitted. Sensitive information will be transmitted through expensive, highly secure lines. If required by law, the information might have to be transmitted to a computer center in the same country as the device. By contrast, less sensitive data will be transmitted inexpensively by means of cloud-based services.

Around-the-Clock Service. One of the future cRSP architecture's main aims is to enable the creation of new business models. Customers already can often choose between a basic service, which encompasses remote-distance diagnostics and software updates, and premium services with a 24/7 repair warranty. The pressure to innovate is especially high in the medical technology sector, says Sandner: "Our competitors now offer remote-distance diagnostics and even the proactive detection of imminent breakdowns."

The next step is to offer interactive services such as audio/video collaboration in real time. For example, a radiologist who is having trouble with an X-ray machine could use the cRSP to establish a video connection with an application specialist at Siemens, who would remotely walk him through the steps needed to resolve the issue. On the other hand, a doctor could obtain a second opinion from a specialist at another hospital. This can already be done through cRSP today, but the next generation of the system will offer better quality even with standard equipment such as tablet computers. And it will enhance not only the company's interaction with customers, but also customers' interactions with one another.

Data analysis is transforming business models through proactive maintenance, energy savings, and remote diagnostics.

Advanced remote maintenance could spur new applications at all Siemens sectors. For instance, experts at Building Technologies are using the cRSP infrastructure and its secure data transmission system to remotely control the facility automation systems in a hospital while their colleagues at Healthcare are using the system for the remote maintenance of computer tomographs in the same building. This approach creates synergies and wins the customer's trust.

Helping customers save energy is becoming an increasingly important business model. For example, Building Technologies is using building management data to advise customers on how to save electricity and cut heating costs. Similarly, Siemens uses data from actual driving operations to give railroad engineers tips on how to operate Siemens locomotives more energy-efficiently. The savings in energy costs are split between the operator and Siemens, resulting in a win-win situation.

In 2014 a new remote maintenance era will also be ushered in at the traffic service center in Munich. In April, a new traffic light control device will be presented. It will be installed in gray cabinets at intersections, but employees will be able to override the system as though they were standing in front of the cabinets. Software updates will be automatically uploaded into the control devices. And here too, the new system will improve efficiency. "This will be especially true for emerging markets, which can't afford to employ large numbers of technicians," says department head Herbert Padinger. Cloud computing is being introduced for the system as well; ten German cities already have their traffic control activities handled by a computer located in another room in the Munich service center. The customers' transport engineers can access the system through the Internet — for example, when they plan to switch all the traffic lights to green for a major event. And they can do this from the comfort of their own homes. ■ *Bernd Müller*

ELVis in the Cloud

Gas turbine testing and validation specialists have to deal with huge data streams to analyze turbine behavior. Outfitted with nearly 10,000 onboard sensors, the latest Siemens turbines may generate an astonishing 12 terabytes (Tb) of data every eight hours. "What if engineers could meet online to monitor all turbine data in real time, without costly and time-consuming travel, but instead collaborating via the Web?" wondered Jochen Luetche, head of Siemens' worldwide large gas turbine testing and validation organization. In response, a joint team of Berlin test field engineers led by Michael Zidorn together with Corporate Technology's researchers in Russia, led by Alexander Loginov, have developed ELVis, a platform that uses the advantages of cloud technologies for collecting, storing, processing, and visualizing large amounts of turbine-based information. During ELVis's development stage, the team focused on three key goals: providing continuous access to huge streams of sensor readings, supplying real-time data analysis based on complex math, and delivering visualization results to multiple locations across the globe. Joint work included a comparative analysis of the latest advances in Web technologies and a look at how ideas from the social network domain (such as information exchange) could be applied to gas turbine monitoring. "We started our R&D in November 2012," recalls Loginov. "By May 2013 the first production version of the software was used worldwide to provide access to Berlin test field experimental data." The project's extremely rapid development resulted from the fact that the hottest but already proven technologies from real-time Web 2.0 and cloud computing were utilized out-of-the-box. These gave ELVis a highly scalable architecture that makes its use equally easy both in laptops and multi-site computing clusters. To use the system via an Internet browser, a registered user needs only a computer and a special card for secure access. Neither extensive local software resources nor physical access to Siemens' Test Bed Center in Berlin are needed. As a result, over 100 experts can now monitor tests of new turbines remotely from their home facilities, thus sharply reducing travel costs and increasing their availability. Cooperation between Siemens' Energy Sector and CT Russia has proved to be very productive. ELVis is already making Siemens' turbine monitoring business much more efficient. It's also applicable to a range of complex technical systems in the rapidly growing industrial monitoring sector. *Natalia Donets*

In the future, walkers equipped with cameras, a Kinect sensor (middle), and a touchscreen (right) could help seniors navigate.

Wonder Walker Gains Traction

As part of the EU-funded DALi project, Siemens researchers are developing a high-tech walker that will safely guide people with cognitive limitations through public buildings. In the future, this technology could also be used by machines in factories.

The bracelet on the elderly woman's left wrist vibrates vigorously. She instinctively steers her walker to the left, away from the freshly mopped patch of floor in the crowded shopping center. With all the commotion, she hadn't noticed the yellow warning sign. And and in any case, her eyes aren't what they used to be — hardly surprising for someone almost 90 years old. But now, she wonders, in which direction is the bakery? Here again, her intelligent walker helps her to stay oriented — literally. Earlier, she had tapped the "bread" symbol on the large touchscreen located between the handles. Now, the bracelets and the walker will safely guide her to her destination, through a veritable slalom course consisting of two groups of schoolchildren, a construction area, and a cleaning crew. It may be a slow trip, but progress is steady and, most importantly, reliable.

Josef Alois Birchbauer works for Corporate Technology — Siemens' central research department — in Graz, Austria. If he has his way, this imaginary scenario will soon be a reality. Together with a consortium of universities and companies from eight EU countries, he has been working for two years on a technology that will help seniors to continue participating in public life. His work is part of the EU-funded DALi project. "Many older people can't cope with the world outside their homes," says Birchbauer. "For them, large public buildings, such as shopping centers, are particularly confusing. For people with special needs, even a trip to a bakery at the mall can be a challenge." A high-tech walker could provide assistance by recognizing signs, autonomously navigating around obstacles, knowing the quickest way to the nearest toilet, and automatically guiding its user through the daily hustle and bustle.

What makes all of this possible are the many digital sensing devices that are built into the C-Walker. These range from high-resolution cameras to a Kinect sensor — a Microsoft device that is used in the Xbox game console. "With its sensor system, the walker can perceive and interpret its spatial environment in real time," explains Birchbauer. "Similar to the way radar operates, the walker senses the position, speed, and direction of movement of people in its immediate vicinity, and it updates this information at a rate of up to ten times per second." If it recognizes an obstacle, it suggests a change of course to its operator — perhaps through vibrations in special bracelets. If the user has tapped in a specific destination, the smart walker will calculate a route around the obstacle, just like the GPS device in a car.

Testing in Spain. Researchers have already developed the first prototypes. To achieve this they had to shrink the complex technology down to the size of a DVD player. "The walker has to be not only as smart as possible but also as maneuverable as possible," says Birchbauer. In December 2013, the first walkers demonstrated what they are capable of at a location in Spain south of Madrid. There, they guided researchers through an obstacle course in a simulated shopping center. The project's partners agreed that the walkers worked flawlessly. Of course, the technicians, software experts and engineers working on the project were comparatively spry. In the next step, the walker's components will be refined and better integrated. The goal is to have a device ready to present to the public by the beginning of 2015. When and if the "wonder walker" will be commercialized is still not clear. "I can imagine the device being checked out for use in large public buildings," says Birchbauer.

The technology that turns a basic walker into a digital mobility assistant will undoubtedly also be used in other environments. Integrated into data glasses, it could warn production plant employees of danger zones and show service technicians the fastest way through a factory (p. 82). "Consider a forklift. With our technology, it could transport its load through an assembly hall autonomously," says Birchbauer. "It would be able to react to obstacles and avoid people — or even interact with them." For Siemens, he adds, these developments are an important step on the road to an intelligent industrial environment. "Today, people have to watch out for machines. In the future, it could be the mechanical 'employee' that watches out for humans." ■ *Florian Martini*

The Economic Impact of Digital Expansion

The move toward digital technologies is thoroughly transforming the economic value chain. According to Bitkom, a German IT association, sales of products and services from the information and communications technology (ICT) sector rose by 3.8 percent worldwide in 2013, to the record value of €2.84 trillion. "As a result, global ICT markets will probably once again grow faster than the economy as a whole," predicts Bitkom Managing Director Dr. Bernhard Rohleder.

At 27.1 percent, the U.S. has the biggest share of the global ICT market. The EU's share is 21.3 percent. It is closely followed by the BRIC countries (18.7 percent), where the ICT market is also growing the fastest. But experts predict that in just a few years, most data will be coming from emerging markets such as China and India. According to the IDC, these markets will account for 62 percent of the digital universe in 2020.

The digital transformation's importance for businesses is demonstrated by a global survey that the IBM Institute for Business Value and the University of Oxford's Saïd Business School conducted in 2012. The survey covered more than 1,000 experts from a variety of sectors. Almost two thirds of the people surveyed said that the use of data and analytical processes provides their companies with a competitive edge. In 2010 the corresponding figure was only 37 percent.

However, it's not just a question of managing the sheer mass of data, but also of controlling the speed and variety of the data. That's a huge challenge, because the digital universe is expected to consist of 40 zettabytes of data in 2020, according to a study conducted by the market research and consulting firm International Data Corporation (IDC). A zettabyte has 21 zeros.

The increase would mean that the data volume would grow 50-fold within ten years. In its study, IDC also estimates that only three percent of the world's data has been tagged to date so that it can be found on the Web under the appropriate subject headings. The amount of data that is actually being analyzed is even lower. IDC calls this situation the big data gap.

Digitization also has a huge impact on the economy and society, as demonstrated by a study conducted by the international strategy consulting firm Booz & Company for the World Economic Forum's *Global Information Technology Report 2013*. According to the study, a 10 percent increase in a country's digitization rate leads to a 0.75 percent higher gross domestic product (GDP) per capita and a 1.02 percent lower unemployment rate.

That's why Booz & Co. has come to the conclusion that the use of digital services by consumers, companies, and governments is more than four times as efficient as the previous expansion of broadband access. Crucial factors for a country's digitization rate are the widespread use of information and communications technology and the existence of appropriate political conditions.

For developed countries, the increased use of digitization primarily benefits economic growth, while in emerging markets it is primarily used to create new jobs. Whereas the use of digital technologies resulted in the creation of almost 400,000 new jobs in North America and western Europe in 2011, it led to the creation of nearly 3.5 million new jobs in the Asia-Pacific economic region. According to Booz & Co., there is insufficient data about the economic sectors in which the new jobs are being created. However, the situation in the U.S. and Mexico shows that many U.S. companies are tending to relocate their operations to Mexico, due to the lower wages and salaries there. The main tasks that are relocated include financial services and production and trade processes.

An important precondition for many digital services is the existence of a dynamic cloud computing infrastructure. IDC estimates that in 2020 nearly 40 percent of all data will come into contact with cloud computing at some point between its creation and use. As a result, the number of cloud servers will grow tenfold worldwide. However, the U.S. software firm Symantec found out that only 17 percent of more than 3,000 companies surveyed worldwide used cloud storage in 2013.

There is a big difference in the use figures for large companies (26 percent) and small and medium-size enterprises (7 percent). Symantec states that the main reason why companies decide not to use cloud computing is their fear of hidden costs. For European companies, the highest priority at the moment is to invest in better IT security, with more than two thirds of respondents stating that this topic is very or extremely important to them. Only two percent of respondents replied that for them investments in IT security are currently unimportant. These results were reported by BITKOM on the basis of a recent study conducted by the European Information Technology Observatory (EITO).

Another study by Booz & Company, *Navigating the Digital Future,* shows that companies worldwide spend an average of 8.1 percent of their research and development budgets on digital tools. The percentages were highest among the sectors for software/Internet, aerospace/defense, and healthcare. The ten most important technology trends include the modernization of infrastructure and the use of mobile devices such as smartphones and tablet computers.

For 55 percent of companies, the integration of mobile solutions into work processes has a high or very high priority. The use of mobile applications for smartphones and tablet computers is correspondingly widespread; that's why Apple and Google now offer more than 700,000 apps. According to Appnation Research, apps generated around $72 billion in business in 2013, and this figure is expected to more than double to $151 billion by 2017. However, these results include all the income from the sale of products via apps. Apps alone currently generate about $25 billion in sales. Although most apps are used today in the entertainment industry and the end consumer business, they will increasingly be employed for manufacturing as well.

Advances in information and communications technology are causing factories to be increasingly connected to the Internet in order to open up new dimensions in production efficiency. The term Industry 4.0 is used to refer to the fourth industrial revolution, following those of mechanization, industrialization, and automation. This new industrial revolution is still a way off, however, as the example of Germany clearly demonstrates.

A survey of German manufacturing companies that was conducted by the Fraunhofer Institute for Industrial Engineering (IAO) showed that less than one fourth of the businesses surveyed were either highly or fully automated. According to the respondents, the main obstacles to the creation of a smart factory are the still unresolved questions concerning IT security, a lack of standards, the high qualifications needed by personnel, the as yet insufficient performance of the information and communications infrastructure, as well as high investment costs.

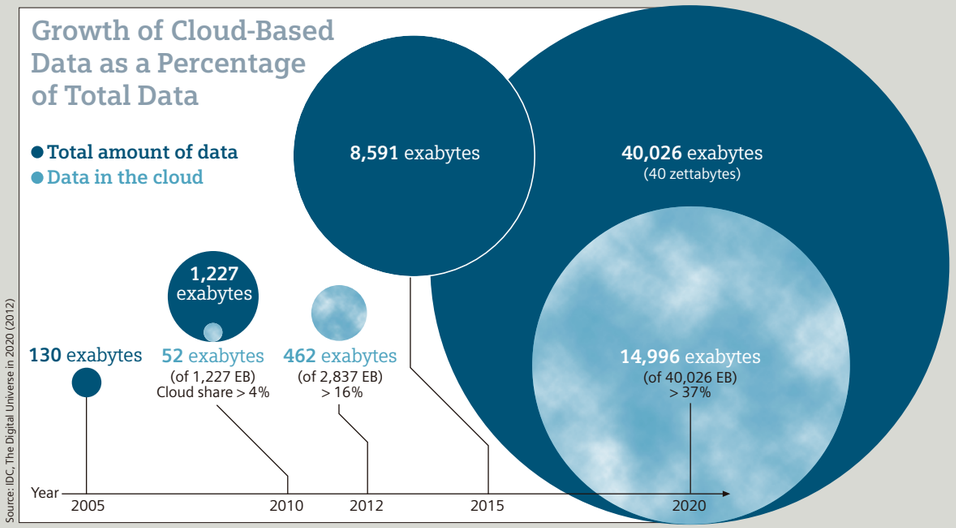
■ *Gitta Rohling*

Comparative Worldwide Expenditures by Major Industrial Segments in Digital Tools

	Digital tools' share of R&D expenditures	Total expenditure on digital tools in US$
Software + Internet	15.0 %	7.7 billion
Aerospace + defense	12.0 %	2.6 billion
Healthcare	10.0 %	13.8 billion
Consumer goods	7.9 %	1.7 billion
Chemicals + energy	7.2 %	2.9 billion
Industrial goods	7.1 %	4.7 billion
Telecommunications	6.9 %	1.0 billion
Automotive	6.3 %	6.5 billion
Computers + electronics	5.7 %	9.7 billion
Other	8.6 %	0.9 billion

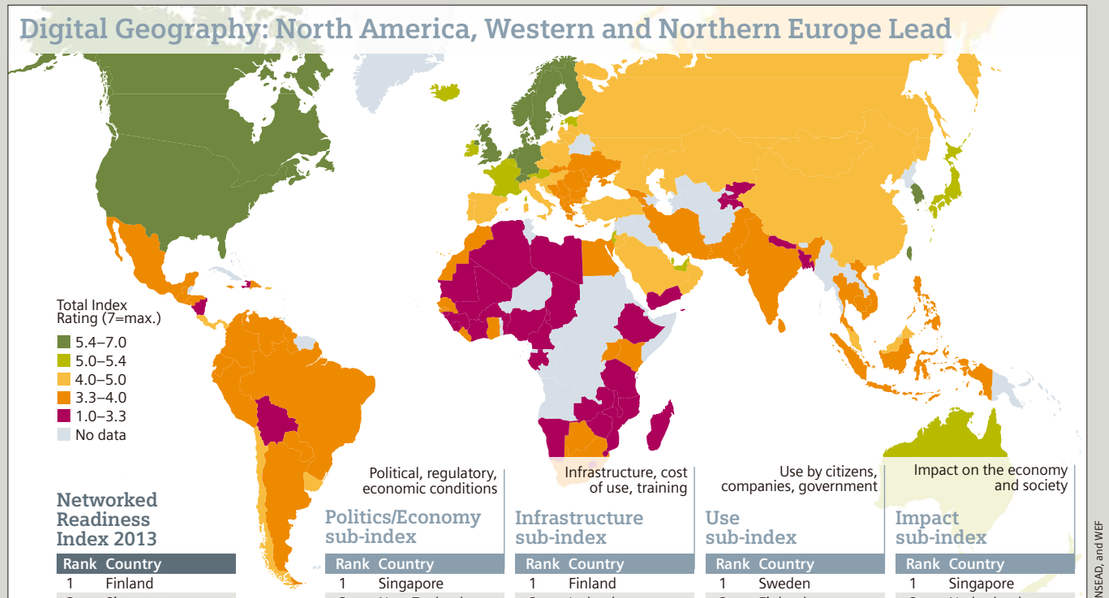
Source: Booz & Co., Navigating the Digital Future (2013)

Growth of Cloud-Based Data as a Percentage of Total Data



Source: IDC, The Digital Universe in 2020 (2012)

Digital Geography: North America, Western and Northern Europe Lead



Networked Readiness Index 2013

Rank	Country
1	Finland
2	Singapore
3	Sweden
4	Netherlands
5	Norway
6	Switzerland
7	UK
8	Denmark
9	U.S.
10	Taiwan
11	South Korea
12	Canada
13	Germany
14	Hong Kong
15	Israel

Political, regulatory, economic conditions

Politics/Economy sub-index

Rank	Country
1	Singapore
2	New Zealand
3	Finland
4	Netherlands
5	Sweden
6	UK
7	Switzerland
8	Hong Kong
9	Norway
10	Canada
11	Australia
12	Denmark
13	Luxembourg
14	Qatar
15	Ireland

Infrastructure, cost of use, training

Infrastructure sub-index

Rank	Country
1	Finland
2	Iceland
3	Sweden
4	U.S.
5	Canada
6	Norway
7	Denmark
8	Switzerland
9	Australia
10	UK
11	Singapore
12	Cyprus
13	Netherlands
14	Germany
15	Belgium

Use by citizens, companies, government

Use sub-index

Rank	Country
1	Sweden
2	Finland
3	Singapore
4	South Korea
5	Netherlands
6	Denmark
7	Norway
8	Switzerland
9	Japan
10	Luxembourg
11	UK
12	Germany
13	U.S.
14	Israel
15	Taiwan

Impact on the economy and society

Impact sub-index

Rank	Country
1	Singapore
2	Netherlands
3	Finland
4	Sweden
5	South Korea
6	Taiwan
7	Israel
8	UK
9	Switzerland
10	U.S.
11	Norway
12	Hong Kong
13	Denmark
14	Germany
15	Estonia

Source: The Global Information Technology Report (2013), INSEAD, and WEF

A Revolution that's Rewriting the Laws of Economics

Everything from magazines to medical records is migrating to the digital world. In what ways is all of this affecting economics and society?
Brynjolfsson: Digital technologies have very different economic characteristics than technologies of the past, such as those that drove the Industrial Revolution. For instance, digital goods can be copied and those copies can be transmitted anywhere on earth at the speed of light at essentially no cost. What's more, the copies are perfect replicas of the original. Digital technologies can create enormous value. But they can also reduce the need for certain kinds of jobs, thus destabilizing entire areas of work.

Is this process accelerating?
Brynjolfsson: Yes, at an exponential rate. Ray Kurzweil, an inventor and entrepreneur, compared this process to what happens if you put a single grain of rice on the first square of a chessboard, put two grains on the next square, and keep doubling the amount with each square. By the time you get to the 64th square you have a pile of rice that's bigger than Mt. Everest. And yet, if you look at just the first 32 squares, the amounts of rice are quite manageable, amounting to only a few truckloads by square 32. Our society is now starting to enter the second half of the chessboard. The scope of digital technologies is expanding because of the combinatorial nature of innovation. In a combinatorial economy, each idea, rather than using up the stock of ideas, creates building blocks for other ideas. And the new combinations of ideas can be even more valuable than the original ones.

What are the economic implications of all of this?
Brynjolfsson: I believe that we will soon be entering a period of accelerating economic growth. However, we will need new tools to measure what is happening. For instance, software is poorly measured in the U.S. GDP and services that are free are not measured at all. Yet look at Facebook, YouTube, Wikipedia — these are all free services. So as people use Wikipedia, for instance, instead of buying encyclopedias, they have access to knowledge without paying for it. But in terms of official GDP, it is a big zero. And if you look at official statistics, the share of the information economy as a percentage of GDP hasn't budged in years. Much of the information economy is invisible because the tools for measuring GDP were invented long before the information economy became important.

What are the consequences of digitization for the job market?
Brynjolfsson: Manufacturing employment, for instance, is declining across the board. Today, there are about 20 million fewer people working in manufacturing in China than there were in the late 1990s. That's about a 20 percent decrease. Why? A robot can perform a simple job such as packing boxes for about $4.00 per hour; but it can work 24 hours per day. So if you have a high school education in the U.S. or are a Chinese factory worker, you are in the bull's eye. It is not that jobs are migrating from the U.S. to China, but that manufacturing jobs in both countries are migrating to robots. The result is that in the U.S. today, although GDP has grown significantly and the net wealth of the nation is at a record $77 trillion, the median income is no higher than it was in the late 1990s. Instead, wealth has been concentrated in a relatively small share of the population. Unfortunately there is no economic law that says that technological progress has to benefit a majority of people.

Are white collar jobs also at risk?
Brynjolfsson: Yes. Take jobs like accounting and bookkeeping, for instance. Today there are around 17,000 fewer tax preparers in the U.S. than there were only a few years ago. They have been displaced by software. What's more, the companies that produce such software can be run with very few people. For instance, Instagram, which specializes in sharing photographs, was sold for over $1 billion yet had a team of only 14 people. Compare that with Kodak, which had nearly 150,000 employees in the 1990s. The underlying trend is that when you shift from manipulating atoms to manipulating bits you need far fewer resources and have much more profit.

Would you call this good news or bad news?
Brynjolfsson: It should be good news because all sorts of information that's extremely expensive today — medical, legal, financial, to name a few key areas — will be much cheaper in the future, and overall income will be higher. But this is also very disruptive for those who are affected.

In other words, you expect digital technologies to benefit average people?
Brynjolfsson: Don't get me wrong. I think that there are huge challenges, such as those we've been discussing with regard to employment, but on balance what we are talking about is mostly good news. Take health care, for instance. Big data will increasingly be used to find patterns in drug interactions and in determining which treatments are most effective. And I believe that bioinformatics, primarily with regard to genomics, will be one of the big stories of the 21st Century. Average people will also benefit from improvements in urban infrastructures, including buildings, communications and transportation networks. The reason? Trillions of Internet-connected devices will collaborate in real time to optimize efficiency, thereby improving services while probably reducing costs.

And what about the energy sector?
Brynjolfsson: We are certainly making progress in terms of cheaper energy sources. And there are now steps in the direction of making electrical systems that are capable of communicating with information networks in order to combine their demand with renewable energy production. An extremely important story here is that we are witnessing an exponential improvement in the energy efficiency of computation itself. This is what is sometimes called "Koomey's Law." Dr. Jon Koomey noted that the cost of computation — in energy terms — is improving even more rapidly than the technologies covered by Moore's Law. When you put all of this together — supply side improvements, remarkable advances in potential for demand management, and the improvement in the energy efficiency of computation — it makes me pretty optimistic about our energy future.

Where do you see the most rapid digitization?
Brynjolfsson: The leading areas today are the media, retailing, finance, and manufacturing. The ones that are coming are health care and education. These are two very positive areas. Take massive open online courses — MOOCs, for instance. These hybrid teaching systems have the potential of taking the very best lecturers and learning systems and replicating them so that they are available to millions of people. Furthermore, in such digital environments every interaction is measured and quantified, which leads to rapid learning about which techniques work and which ones don't. These characteristics can lead to a higher rate of improvement in learning and teaching.

Erik Brynjolfsson...

...is the Schussel Family Professor of Management Science, a Professor of Information Technology, and the Director of the MIT Center for Digital Business, a research initiative that analyzes the business uses of the Internet and other digital Technologies, at the MIT Sloan School of Management. Brynjolfsson holds an AB in applied mathematics from Harvard College, an SM in decision sciences from Harvard University, and a PhD in managerial economics from MIT. He is the co-author of three books: *Wired for Innovation*, *Race Against the Machine*, and, most recently, *The Second Machine Age*. Prof. Brynjolfsson is also Chairman of the Board of the MIT Sloan Management Review.

Do you believe we are headed for technological singularity — the concept of machine intelligence eventually equaling or exceeding human intelligence?
Brynjolfsson: I think there's a lot of good science behind this idea. The engineers I know are confident that exponential improvements in artificial intelligence — AI — will continue to be realized for at least another decade. Eventually, it's likely that we will have computers that operate at human or superhuman levels of intelligence. We could ultimately have computers that design even better computers, and AI that creates even better AI. This is what people talk about with regard to singularity: a positive feedback loop that leads to very rapid acceleration, possibly within our lifetimes.

Could all of this lead to a world of non-interpretable results — systems that propose solutions that are based on such huge data sets that we cannot fathom them?
Brynjolfsson: This is an unfortunate side effect of many neural nets and big data algorithms. The results are accurate, but the explanations cannot be unpackaged for human consumption.

What should society be doing to prepare for an increasingly digital world?
Brynjolfsson: As Andrew McAfee and I say in our latest book, *The Second Machine Age*, technology is not our destiny; we shape our destiny. What that means is that we must be much more conscious about what kind of society we want to live in, what our values are, what our goals are, and explicitly demand this from our political leaders and ourselves. The technologies we've been discussing are enormously flexible and can be used to create enormous wealth. But that wealth can be concentrated in the hands of a small number of people or it can create widespread opportunity for billions of people. It can be used to create unimaginably destructive weapons, or to improve health care and to eliminate hunger. It can be used to eliminate privacy, or it can be used to enhance it. We realize that the failure to keep up with technology is hurting a lot of people right now. But if we do things right, it can help everyone. We certainly have it within our power to create shared prosperity. But that will never happen if we just close our eyes and assume it's going to happen on its own.

■ *Interview conducted by Arthur F. Pease.*

At Siemens' Amberg Electronics Plant, Simatic programmable logic controls (PLCs) manage the production of PLCs.

Defects: A Vanishing Species?

Want to know how manufacturing will change over the next few years? Then take a look at Siemens' electronics plant in Amberg, Germany. There, products already communicate with production machines, and IT systems control and optimize all processes to ensure the lowest possible defect rate.

Everything is clean and germ-free. Looking for a piece of dust here is comparable to searching for the proverbial needle in a haystack. Employees wear blue coveralls and walk noiselessly across spotless white-and-blue marble-patterned PVC floors. Chest-high blue-and-gray machine cabinets stand in a row. Between them are monitors displaying floods of data that scroll downwards like waterfalls. Indicator lamps flash red and green, while long rows of halogen lamps bathe the hall in a bright, cool light.

A little daylight filters into the hall through a few slit-like windows that reach from floor to ceiling. The light shows that spring has finally arrived. Assembly lines clack, a forklift hums, and air-controlled valves hiss. What seems at first glance to be as antiseptic as a hospital operating room is in fact the factory hall of Siemens' Amberg Electronics Plant (German abbreviation: EWA).

Instead of treating patients, the facility, which Siemens established in 1989, produces Simatic programmable logic controls (PLCs). The devices are used to automate machines and equipment in order to save time and money and increase product quality. They control ski lifts and the onboard systems of cruise ships as well as industrial manufacturing processes in sectors from automobile production to pharmaceuticals.

Siemens is the world's leading PLC supplier, and the EWA is the company's showcase plant for these systems. Production quality is at 99.9988 percent, and a series of test stations detect the few defects that do occur. "I don't know of any comparable plant worldwide that has achieved such a low defect rate," says Professor Karl-Heinz Büttner, who heads the EWA. The factory manufactures 12 million Simatic products per year. At 230 working days per year, this means that the EWA produces one control unit every second.

Production is largely automated. Machines and computers handle 75 percent of the value chain on their own; the rest of the work is done by people. Only at the beginning of the manufacturing process is anything touched by human hands, when an employee places the initial component (a bare circuit board) on a production line. From that point on, everything runs automatically. What's notable here is that Simatic units control the production of Simatic units. About 1,000 such controls are used during production, from the beginning of the manufacturing process to the point of dispatch.

Three-quarters of the Amberg plant's production steps are automated; the remaining 25 percent are performed by humans.

Over 60,000 Customers Worldwide. At the beginning of the manufacturing process, conveyor belts take the bare circuit boards to a printer, which uses a photolithographic process to apply a lead-free solder paste. In the next step, placement heads mount individual components, such as resistors, capacitors, and microchips, onto the circuit boards. The fastest production line can mount 250,000 components per hour — a process that is controlled by Simatic units. Once the soldering process has been completed, the printed circuit boards arrive at an optical test system, where a camera examines the position of the soldered components while an X-ray machine inspects the quality of the soldered connection points. Next, each printed circuit board is mounted into a housing. It is then retested and sent to a delivery center in Nuremberg. From there the PLCs are shipped to more than 60,000 customers all over the world. About 20 percent are sent to China; the rest are mainly sold to customers in Germany, the U.S., and Italy.

Although production in Amberg is highly automated, human beings ultimately make the decisions. For example, Johannes Zenger, 26, supervises the test station for populated printed circuit boards, even though he himself doesn't test the components and circuitry. "My workplace is the computer," he says. Like his colleagues, Zenger can monitor the entire value chain from his workplace. That's because each circuit board has its own unique barcode that lets it communicate with the production machines. More than one thousand scanners document all of the manufacturing steps in real time and record product details such as soldering temperature, placement data, and test results. As this happens, around 50 million pieces of process information are generated each day and stored in the Simatic IT manufacturing execution system. "In short," explains Büttner, "we can observe every product's lifecycle down to the last detail."

Every day, one thousand scanners collect around 50 million pieces of process data on individual products.

Software defines all of the manufacturing processes and commands so that production can be recorded and controlled from start to finish. The system is also closely networked with the R&D department. NX and Teamcenter, both of which are Siemens PLM software solutions, directly supply the manufacturing processes with the latest Simatic updates. Because the Amberg plant manufactures a thousand different products, very close cooperation with the plant's R&D department is essential.

Talking Products. The Amberg Electronics Plant is an advanced example of Siemens' Digital Enterprise Platform — a production environment that could become standard ten years from now. Here, products control their own manufacturing processes. In other words, their product codes tell production machines what requirements they have and which production steps must be taken next. This system marks the first step toward the creation of Industry 4.0 (*Pictures of the Future*, Spring 2013, p. 19).

In this vision of a fourth industrial revolution, the real and the virtual manufacturing worlds will merge. Factories will then be largely able to control and optimize themselves, because their products will communicate with one another and with production systems in order to optimize manufacturing processes. Products and machines will determine among themselves which items on which production lines should be completed first in order to meet delivery deadlines. Independently operating computer programs known as software agents will monitor each step and ensure that production regulations are complied with.

The Industry 4.0 vision also foresees factories that will be able to manufacture one-of-a-kind products without being unprofitable, as they will produce items quickly, inexpensively, and in top quality.

In spite of its highly automated processes, EWA nevertheless relies on people for the development and design of products, production planning, and the handling of unexpected incidents. That won't change in the future. "I doubt whether there will be any machines in the foreseeable future that can think independently and work intelligently without human aid," explains Büttner. This assessment is confirmed by a glance in the EWA hall. Around 300 people work the current shift, and the EWA has a total of about 1,100 employees.

Quality at Siemens' Amberg plant is now more than 40 times better than 25 years ago.

One of them is Sabrina Scherl. She's a good example of why human beings are still indispensable even in highly automated production facilities. Scherl is a trained photo lab technician who has worked at the EWA as a machine operator for the past nine years. In addition to loading a machine with rolls on which individual components are lined up, Scherl is responsible for quality testing. She visually checks the populated printed circuit boards on a computer to make sure they are complete. Without Scherl the fully automated machine would be unable to proceed.

Humans and machines work together to test the quality of Simatic controls.

Human Beings as a Success Factor. "We're not planning to create a workerless factory," says Büttner. After all, the machines themselves might be efficient, but they don't come up with ideas for improving the system. Büttner adds that the employees' suggested improvements account for 40 percent of annual productivity increases. The remaining 60 percent is a result of infrastructure investments, such as the purchase of new assembly lines and the innovative improvement of logistics equipment. The basic idea here, says Büttner, is that "employees are much better than management at determining what works or doesn't work in daily operation and how processes can be optimized." In 2013 the EWA adopted 13,000 of these ideas and rewarded employees with payments totalling around €1 million. In 2012, for instance, Zenger suggested that his test station's collision needle be replaced with three collision sensors. His suggestion was a big success, because the needle could only roughly determine a component's position on a printed circuit board. "By contrast, the three sensors can determine the components' front and back edges as well as any twisting," says Zenger. As a result of this idea, previously undetected faults can no longer occur.

Although the EWA is highly automated, its appearance hasn't changed much since 1989. "The plant now has more and bigger machines than it did 25 years ago," explains Norbert Eckl, Head of Factory Planning at the EWA plant. However, a closer look reveals that work processes and results have also changed considerably. Even though the production area has remained unchanged and the number of employees has hardly increased, the plant now manufactures seven times as many units as it did in 1989.

More importantly, quality has increased substantially as well. Whereas the production facility had 500 defects per million (dpm) back in 1989, it now has a mere 12 dpm. "That's an impressive achievement," says Büttner with pride. In the background, you can hear assembly lines clack, a forklift hum, and air control valves hiss. Although the EWA isn't a hospital, it is something like a birthplace for cutting-edge automation technology.

Ulrich Kreutzer

At Siemens' Chengdu plant, most production processes are automated, resulting in an error rate close to zero.

How to Export a Success Story

Siemens is exporting "Made in Germany" to Chengdu, China. In 2013 the company built a highly automated factory modeled on its Amberg Electronics Plant. The Chinese plant builds Simatic programmable logic controls. Its computer-controlled systems monitor and manage all of its development and production processes.

The small Bavarian town of Amberg and the Chinese megacity of Chengdu have little in common, yet each is home to a state-of-the-art Siemens production facility for automation technology. But although the Amberg Electronics Plant (German abbreviation: EWA) was built in 1989, the Siemens Electronic Works Chengdu (SEWC) only opened in February 2013. Siemens manufactures Simatic programmable logic controls (PLCs) at both locations. PLCs are used to control the full range of industrial manufacturing processes — regardless of whether the facilities are gravel pits, automobile plants, or paper factories.

For over 20 years, Simatic production was concentrated at the EWA plant. Today, 75 percent of the facility's production processes are automated and the plant has an impressively high quality rate of just 12 defects per million. The plant's Simatic IT manufacturing execution system monitors and controls the entire production process. It does so virtually — in part by using data that the products supply directly to production machines.

In 2011 Amberg's managers decided that the plant's recipe for success could also work in China. "Production capacity had reached its limits at the EWA, so we had to either expand or build a new plant somewhere else," explains Jochen Berger, project coordinator for Industry Automation Systems at the EWA.

Chengdu was selected due to strategic considerations. China is one of Siemens' main sales markets, accounting for 20 percent of the Amberg plant's production output. And that's no wonder, because China is the world's largest market for automation technology. "We want to be where the customers are," says Berger. In addition to setting up a production facility, Siemens created R&D capacity in Chengdu, as this is the only way Siemens can quickly and efficiently implement China-specific customer requirements and introduce new products. As a result, most Simatic products that are earmarked for the Chinese market will be manufactured in China itself in the future.

The Siemens Electronic Works Chengdu is the first manufacturing facility in China to be made of products from Siemens' Digital Enterprise Platform. All of the plant's processes are IT-controlled, from development and product design to manufacturing and processing. The plant uses the same technologies as the facility in Amberg. This means that NX and Teamcenter, both high-performance PLM programs, ensure that data is directly exchanged between the product development department and the manufacturing center. The programs help developers design and simulate new products. They then forward all product information from R&D processes to the Simatic IT manufacturing execution system, which controls the entire production process in real time.

The system receives up-to-date information from the products it produces. Through its unique barcode, each workpiece continuously provides numerous sensors with information regarding its status, its requirements, and the next production steps. This is the only way that increasing product complexity can be easily managed, because Siemens plans to manufacture many different product versions in Amberg and Chengdu in the future. The system will also greatly simplify data sharing between developers, product engineers, and production engineers.

Amberg: Role Model. Employees in Chengdu are proud of this system architecture. "I really like the SEWC, because all of the production processes are managed by an integrated IT system," says Li Yan, who works in the Logistics department. Chengdu's highly automated production process doesn't just interest Siemens employees; the plant also attracted more than 2,000 non-Siemens visitors in its first year of existence.

The plant in Amberg is the role model for the Chengdu factory. "We only want to use proven systems from the EWA," explains Stefan Gottwald, Commercial Director of the SEWC. However, the factory in Chengdu still isn't identical to the one in Amberg. Because the SEWC is still being set up and expanded, its performance doesn't yet match that of the Amberg plant. Whereas the EWA manufactures one million Simatic products per

month, the SEWC produces only 60,000. But at 3,200 square meters, the Chengdu facility is only one third the size of the Amberg plant. SEWC's output is set to quadruple in the future. Its low production figures are also the reason why the Chengdu plant still hasn't reached the Amberg facility's 75 percent automation rate. The same applies to product variety, with production concentrating on the Simatic S7-200 control system and just a few other components. In Amberg the figure is around 1,000 different products. But the SEWC is adding between four and six products to its production volume every month.

Employees are encouraged to suggest improvements. But this mindset must become more widespread in China.

The fact that the SEWC is still in the start-up phase is also reflected in its workforce. Whereas 1,100 people work in Amberg, the plant in Chengdu has only around 350. Moreover, many of them don't work in manufacturing, because they are required to take on duties in production planning, quality planning, purchasing, and logistics that machines cannot perform. "As production increases, we plan to hire more and more people," says Andreas Bukenberger, Technical Director of the SEWC. This also applies to the management level, where key positions are still held by Germans. "Ultimately, our goal is to fill all of the management positions with Chinese experts," explains Bukenberger.

Culture Transfer. Production processes and workforce structure aren't the only things that are increasingly becoming similar to those in Amberg. Siemens also plans to establish the Bavarian plant's corporate culture in Chengdu. This is no easy task. Idea management is a key factor for the Amberg plant's success, but workers in China are not used to taking the initiative in making suggestions for improvements. "The required mindset is almost nonexistent among Chinese employees," says Bukenberger, who is satisfied with even minor achievements. "The important thing is not whether every employee makes one or ten suggestions per year, but whether we can encourage everyone to contribute beneficial ideas," he says. To stimulate this process, the plant has launched a 3i (Ideas, Initiatives, Impulses) program, in which employees receive monetary or other rewards to encourage them to suggest improvements. The best proposals are published each month and the employees who had the ideas receive certificates.

To help the Chinese employees better understand the Amberg model, the SEWC and the EWA plan to bring Chinese and German colleagues together at technology days to be held twice a year. In addition, more than 80 employees holding key positions at the Chengdu plant were given the opportunity to get to know the corporate culture and production processes in multi-month training programs in Amberg. Soon, the two plants will also share technology. Until now, however, know-how transfer has been a one-way street. But in the near future successful ideas from Chengdu will also be adopted in Amberg.

Although the two facilities are being networked more and more closely with one another, the Chengdu plant is trying to become more independent of Amberg at the management level. This is happening not only in the area of recruiting but also in purchasing and customer contacts. In the first months of its existence, the Chinese plant obtained all of its materials from Amberg and sent all of the S7-200 controls it made to Germany so that their quality could be checked. Employees in Chengdu now test their products themselves. "However, we closely coordinate all strategic decisions with the EWA," explains Bukenberger. "We still can't do everything by ourselves." For one thing, the plant still has to establish supplier relationships with Chinese companies from which the SEWC will procure printed circuit boards and components. However, Chinese partners will first have to ensure that they can supply the parts reliably and on time. "For us to grow, it will be essential that high-quality basic materials are always available," explains Bukenberger.

Award Winner. Even though the Chinese plant is still being set up, it has already made a name for itself. The SEWC is the first factory in Chengdu to receive the LEED Gold certificate, an award for efficient energy supply systems and environmentally friendly building technology. Compared to similar buildings, the SEWC consumes around 2,500 metric tons less water, emits 820 metric tons less CO_2, and cuts energy costs by an estimated €116,000 per year. These savings are the result of smart building technologies such as climate-control systems, energy-saving pumps, and energy-efficient lighting. Siemens did not install solar panels, because Chengdu is located in a very rainy region.

The Chengdu facility has ambitious targets. "We expect to grow by 50 percent in 2014," says Bukenberger. To achieve that goal, more employees will have to be hired for production operations. The factory also plans to expand its 3,200-square-meter footprint. "If demand for our products is sufficiently high, the SEWC will triple in size in the next 15 years," Bukenberger explains. Once that goal is achieved, Chengdu will match not only the quality of its role model in Amberg, but also its size. ■ *Ulrich Kreutzer*

Some 350 employees in Siemens' Chengdu plant ensure that high-quality products are manufactured in southwest China.

The Bavarian State Library's collection is being scanned and uploaded to the Internet.

Accessing Everything

Since the early 1990s, digital technologies have been fundamentally changing the way we live. Today we are approaching full transformation — the conversion of all documented analog human knowledge into digital form. PoF takes a look back and envisages the future.

Zuse, CERN, Zuckerberg — these three names mark key milestones of the digital revolution. Back in 1941, Konrad Zuse built the world's first functional computer in Berlin. He called this vast digital calculating machine the Zuse Z3. In 1991 the World Wide Web developed by Tim Berners-Lee at the CERN research center in Switzerland became accessible to the global public. The Web went on to revolutionize the way people communicate, and it paved the way for Google, Amazon, and countless other companies. Then, in 2004, Mark Zuckerberg founded the social network known as Facebook. Today, Facebook and similar networks have made it possible for nearly two billion people to develop a digital identity.

Computers, the Web, Facebook — all are based on digitization, which simply means the transfer of analog information such as texts, sounds, images, and video into an easily stored binary code made up of zeros and ones. Once created, such digital items can be reproduced in unlimited quantities without any loss of quality, and distributed around the world in seconds via the Internet. Digitization has created completely new types of sales channels for businesses, but it has also created new problems, such as illegal data copying. The Internet boom that began in the 1990s led to an unprecedented wave of digitization. In 1993 only around three percent of information had been digitally stored worldwide, but by 2007 that figure had skyrocketed to 94 percent. The trend continues unabated, with huge amounts of new data be digitized every day.

One of the most important pioneers of the digital world was the German inventor Rudolf Hell — "the Edison of the graphics industry" and recipient of the Federal Republic of Germany's Grand Merit Cross, the Gutenberg Prize, and the Werner-von-Siemens-Ring. Hell is considered the father of the fax machine and the scanner. In 1980 he commercialized the groundbreaking Chromacom digital image processing system. In the early 1980s the HELL company, which was a Siemens subsidiary at the time, was hired by the Vatican Library to scan and digitally reproduce valuable books in order to make them accessible to the public. During the 1990s, digitization processes became more extensive and systematic. In 1990, for example, Siemens Nixdorf installed a data processing system in the Kremlin Museum in Moscow to digitally catalogue the complete art collection of the Russian czars for the first time. The resulting digital images and information were then documented and categorized in an image database.

Scanning Half-Opened Books. Today, many institutions want to make digital copies of all the analog information they possess. One of the best examples of this is the Bavarian State Library (BSB) in Munich, whose digitization center houses the most extensive range of equipment in Germany. "We use 26 different scanning systems, including four fully automatic scanning robots that can process up to 2,000 pages per hour," says the BSB's Assistant General Director, Klaus Ceynowa. "We have two operators who each monitor two robots. The system isn't just fast;

The Bavarian State Library's entire collection (left) is being digitized. An app is now available to view its most notable treasures.

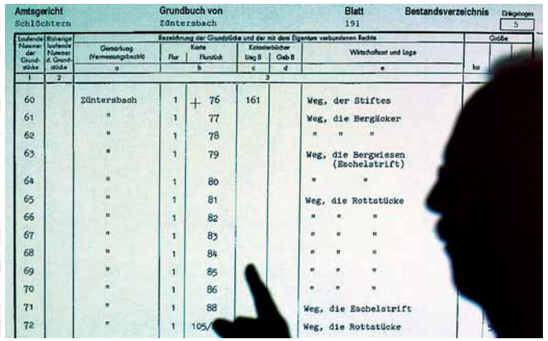
it's also designed to protects books, which only have to be opened at a 60-degree angle. The system's scanning prism is guided into a half-opened book. It reads the pages with perfect clarity and then turns them to move on to the next scanning sequence."

The BSB has been working with Google since 2007 on a Google Books project that will lead to the digitization and Internet publication of one million books from the BSB collection. The books in question were written between 1601 and 1874 and are no longer under copyright protection. "Each week we release around 5,000 books that Google digitizes at its scanning center in Germany," Ceynowa explains. "Google pays for the scanning and gives us digital copies for our own database. All works from before 1601 and after 1874, including very valuable handwritten documents from the Middle Ages, are processed at our own center. The Google project is scheduled to be completed before the end of this year. We've already uploaded nearly our entire collection of one million works to the digital library at our website, where anyone can use them."

Nearly one million works from the Bavarian State Library collection can already be accessed online.

Nevertheless, complete digitization is far from the end of the story at the BSB. "Our work is just beginning," says Ceynowa, "because the things we've done until now open up different kinds of possibilities for linking and recombining digital information." The BSB has developed several mobile apps, including one known as Ludwig II. The app allows people to access historical information, images, and documents related to the king's "fairytale castles" in such a way that the information is tailored to the user's location. For example, people standing directly in front of the king's Residenz palace in Munich can use their smartphone's camera mode to access real-time images of the palace's famous Wintergarden, which no longer exists. The Wintergarden was located on the roof of the Residenz and featured exotic plants and an artificial lake, all of which the app displays.

Digitization of Civil Registries. Museums and libraries are only the latest institutions to take advantage of the benefits offered by full digitization; government agencies and industrial companies have long been using the technology. Germany's 16 federal states now plan to digitize all of their civil registries. To this end, they commissioned Siemens Corporate Technology (CT) to conduct a feasibility study over the last two years under the direction of Dr. Bernt Andrassy. "Germany is basically divided into land parcels," Andrassy explains. "The registries allocate certain rights to these parcels. That makes the registries the central regulatory mechanism for land use in the country. The states have now scanned and archived all registry documents going back 50 years, and CT supplied them with the important system components they needed. We've collected a huge volume of data totaling around 500 million pdf pages."



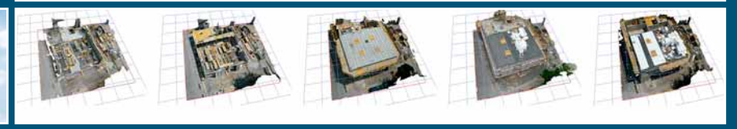
Left: A handwritten 1743 registry from the Brandenburg State Archives (left), and a contemporary electronic registry, as displayed by an employee of the Frankfurt District Court (right).

This vast digital project presented a huge challenge. For example, the Siemens team had to develop automated software that could recognize individual words, understand key issues, and identify connections within the scanned documents, which included typed pages, poor document copies, and documents containing multiple corrections. "One thing the software has to know is which section of a document contains the names of property owners and which sections have information about the size of properties, whether they were mortgaged and, if so, which bank issued the mortgage," Andrassy explains. To solve these issues, experts had to do some intensive programming. "Our software recognizes the required information and automatically fills in the input mask," says Andrassy. "The operator simply checks to see that all the data is there." The states now plan to issue a call for tenders for the gargantuan archiving project. "Once all registries have been digitized, each state will set up its own user portal that will grant fast and easy access to individuals and institutions with a valid interest in the documents — for example, notaries, banks, and tax authorities."

Misreading Can Cost Millions. Andrassy's experience with the registry project can also be applied to the industrial sector. "We are working on a software package that automatically registers the customer requirements in calls for tenders and then compares them with the data in digitized documents from past projects," says Andrassy. "Such calls for tenders usually come in the form of pdf documents that are often more than 1,000 pages in length. Previously, each individual specification — such as the maximum rotation speed of a turbine or the maximum permitted noise level after 4 p.m. for a combined-cycle power plant — had to be extracted manually and then evaluated by an expert."

Flying Foreman

It's one of the biggest and most innovative urban development projects in Europe. The Aspern Vienna Urban Lakeside project is a completely new district on a 240-hectare site on the northeastern outskirts of the Austrian capital. The district is expected to set new standards for energy efficiency and environmental balance (*see Pictures of the Future*, Fall 2013, p.16).



A joint venture between the city of Vienna, the city' utility company (Wien Energie), the city's network provider (Wiener Netze), and Siemens is also using Aspern as a living laboratory for technological innovations. To this end, Siemens has literally taken to the air with state-of-the-art 3-D digitization technology.

"For nearly three years now, we've been working with civilian drones within the framework of the CONSTRUCT — Construction Site Monitoring research project," says Claudia Windisch, Head of the Videoanalytics research group at Siemens Corporate Technology. "The drones, which film and analyze conditions at construction sites, are octocopters — small eight-propeller aircraft that weigh less than five kilograms." The digital aerial technology for monitoring construction progress is being tested in Aspern Vienna and other locations. "We use GPS to define the routes to be flown," Windisch explains. "Operators constantly maintain visual contact with the drones so that they can intervene if there's a problem. However, operators sometimes have to take control of the drones, such as when we record images of a facade." The heavily overlapping aerial images of buildings are used to generate a three-dimensional model of the scene.

Researchers are working on a system that supports drone operators during flights by producing and continually updating a 3-D model and color-coding problematic areas. Additional image recordings are required here to achieve the degree of overlapping that is needed to generate an accurate model.

"These days, most building planning is done in 3-D, so it makes sense to compare real and planning data in 3-D as well," Windisch explains. "If you consider the time axis, you could even say we're working in 4-D. Our technology enables us to identify construction progress and any deviations from a plan. However, because onsite construction managers only have access to two-dimensional plans at the moment, we decided in Aspern Vienna to use 3-D models to generate 2-D depictions of actual situations. You can superimpose conventional 2-D CAD plans on the 2-D images and then compare them."

In the future, the process will be optimized to enable automatic comparisons and the graphic depiction in virtual 3-D models of deviations between planned and actual results. Deviations here could include missing windows or incorrectly aligned walls, for example. "The methods we've developed can detect deviations between planned and actual results simply and quickly," says Windisch. "The deviations can then be displayed in large-scale depictions — and all of this can be done without having to send inspectors to potentially dangerous and difficult-to-access areas, such as unfinished roofs." However, construction sites represent only one of many potential applications for the technology. Windisch's team, for example, has already conducted numerous drone flights through factory halls whose actual condition often deviates from original construction plans due to renovation and modernization measures.

Nils Ehrenberg

But requirement and specification lists are usually extremely long, and a misreading of even one sentence can cause millions of euros in damages later on. With this in mind, experts in Munich developed a reliable search system technology that would notice every change made and then inform users of the alteration. The ultimate goal is for the program to understand and correctly interpret the specifications as semantic objects. "The software we developed works in three stages, which we refer to as Tender Search, Tender Comparison, and Tender Tracer," Andrassy explains. "The first step is a very efficient process that enables the user to find the specifications in a document. In the second step, the software searches for similar specifications from past projects. This makes it possible to utilize the corresponding evaluations made in the past, and thus avoid errors. In the final step, the software tracks the identified specifications throughout all new versions of the document."

The benefits of this approach are clear, as the automated evaluations significantly accelerate processes and allow errors made in similar projects to be identified at an early stage. In addition, the system enables last-minute customer changes and their consequences to be quickly analyzed and integrated into a project.

Combing Archives in Seconds. Full digitization is just the beginning. Whether it's libraries, government agencies or factories — a vast amount of digital knowledge is being created that can be used in completely new ways. Developments over the next few years and decades will therefore focus on software-based tools that can sift through digital archives in seconds, understand semantic connections, and sort and recombine information. "For example, scholars will be able to quickly determine in which manuscripts the term 'novel' was first used," says Ceynowa. "They won't have to search through hundreds of documents in libraries around the world to get the answer. This will truly revolutionize certain research disciplines."

"It will be possible to access things like judicial case law and past medical diagnoses of rare diseases much more quickly," Andrassy adds. "Nevertheless, intelligent data mining still can't replace people — but it can support them. In other words, we're still a very long way off from an autonomous factory that reads customers' pdf files, compares them with its database, and then immediately knows what it has to build and how it has to build it." ■ *Nils Ehrenberg*

How eGovernment Can Strengthen Democracy

In what ways do you expect eGovernment — electronic government services — to change the way government works?

Koulolias: In light of recent economic problems, governments must achieve more with fewer resources. In addition, new policies are required to address global challenges in areas such as public safety, climate change, and the transition to renewable energy. New approaches are also needed to manage an aging society, changing lifestyles, urbanization, and the increasing cost of health care. Public administrations today have to serve informed and educated citizens who have high expectations and hold governments accountable. eGovernment enables a more mature and deeper relationship between the public and the private sectors, greater collaboration among all levels of government, and new service delivery models. eGovernment also allows us to reduce costs, while at the same time improving the quality of services and increasing civic participation. All of these developments strengthen democracy.

In what ways might eGovernment change everyday life?

Koulolias: In a completely connected world, all interactions that have traditionally taken place physically with government will disappear. Telemedicine and technology-based learning will be as natural as electronic tax returns and online banking are today. The same applies to voting, discussions with other citizens, and having your say in parliament.

Might automation in the public sector increase anonymity and alienation?

Koulolias: A feeling of alienation from the political system is a very common phenomenon. However, it usually stems from a lack of responsiveness and participation, not from automation. A system that's responsive to the needs of citizens is not likely to result in alienation. With regard to anonymity, I do not particularly feel that in countries where eGovernment services are rare the citizens enjoy a stronger sense of proximity and familiarity to government.

What's the status of e-Government services in Europe?

Koulolias: The European Commission and some of the EU member states are among the principal driving forces behind the creation of a single digital union. The EU supports open, flexible, and collaborative eGovernment services at the local, regional, national, and European levels. The current eGovernment Action Plan calls for 50 percent of EU citizens and 80 percent of businesses in the EU to use eGovernment services by 2015. I believe eGovernment provides an unprecedented opportunity to drive EU integration forward. Moreover, it is only through eServices that EU citizens can exercise their rights, such as voting, paying taxes or opening a business, across the entire EU. The biggest challenges at the moment are data standardization and the interoperability of eServices across borders. However, we are part of a team that's working on the harmonization of services.

In what areas do you expect citizens to become more involved in decision-making than they are today?

Koulolias: Our research on eGovernment services can be used in a wide range of applications, from health care to business operations. However, the area in which they will have the most profound impact is urban planning. Here, simulations, modeling, and citizen surveys will facilitate interactive decision-making processes. Big data and social media can be used to develop optimal solutions that take into account citizens' preferences at an early stage of a given process. The proposals made by officials and urban planners can then be sent back to the public for consultation and approval. In this way, the public will be involved in the decision-making process as co-creators, rather than simply being asked to choose between a series of already developed options, as is the case today.

How would you describe the characteristics of an eGovernment-based society?

Koulolias: A society in which eGovernment has been firmly rooted would, more than anything else, be an interconnected society. Procedures related to the rights and responsibilities of citizenship would be performed online. As a result, citizens would be able to participate in all aspects of civic life — ranging from town-hall discussions to national consultation processes, elections, parliamentary debates, and urban planning initiatives — all via simple user-centric applications, and without ever having to set foot in a public building. In addition, citizens residing abroad would be able to do everything from changing their address to opening a business or filing their tax returns just as they would at home. Interactions between citizens, businesses, and government agencies would be conducted through trusted inboxes enabled by mechanisms such as eSignatures.

Do you see a potential conflict here between transparency and data privacy?

Koulolias: Data protection and the security of citizen information are crucial. We have to develop an internationally recognized and respected legal framework to protect our online privacy. This applies to both the private and the public sectors.

Vasilis Koulolias

Vasilis Koulolias is an economist and political scientist who has been working for more than 20 years on improving democratic processes through the use of information and communication technology (ICT). Koulolias is the Chairman of the non-governmental organization Government to You, which was named one of the ten most influential political and Internet organizations by PoliticsOnline. Koulolias is an associate member of the non-profit International Council for Information Technology in Government Administration, as well as a member of the Management Board of Spider, a Swedish program for developing ICT systems. He is also the founder and Director of eGovlab, an institute in the Computer Science Department at Stockholm University that studies issues related to eGovernment and citizen services in Sweden.

Couldn't all of this lead to marginalization of those individuals who are technologically handicapped, so to speak?

Koulolias: Advances in technology will further simplify citizens' access to the Internet and eServices. For example, by combining the use of sensors and a smart TV that is connected to the Internet, elderly people will be able to monitor their health condition as displayed onscreen and then share the data with their family members and doctors with a simple command gesture. Wrist smartphones are yet another innovation that has brought the Internet to the less technologically savvy. We're now testing smart TVs and wrist sensors within the framework of eGovlab.

How can eGovernment support democracy?

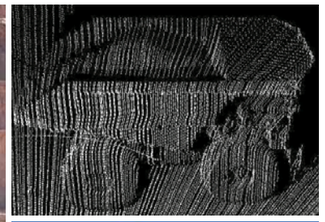
Koulolias: eDemocracy does not necessarily undercut our traditional forms of representative democracy. It's unreasonable to expect that all citizens would want to be fully involved in all aspects of democracy. However, digital communication makes information more accessible, and digital channels make it easier for individuals or groups to communicate with their elected representatives. Digital petitions and eVoting are among the most basic forms of eDemocracy. More evolved mechanisms would allow elected representatives to perform data mining in social networks, or to use open data that is directly or indirectly created by the public. This data would enable elected representatives to make wiser decisions based on their constituents' preferences, instead of making policy along traditional party lines. In this way, eGovernment could make the work of elected representatives more effective.

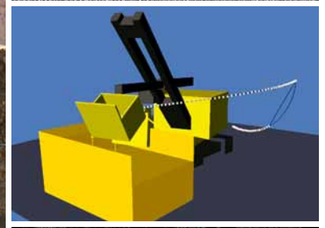
What is your vision of political and social life in 2050?

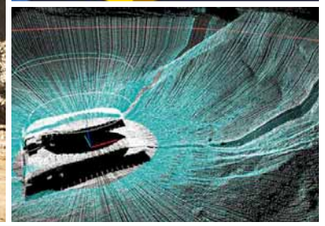
Koulolias: By 2050 the EU will have a fully functional cross-border interoperable eGovernment system that will enable citizens from all EU member states to truly exercise their rights as EU citizens. The power of information and communication technology will have fully transformed our understanding of the role of government. The true implementation of the concept of "we the people" will blur the boundaries between citizens and public administration, and between the public, private, and tertiary sectors.

■ *Interview by Susanne Gold.*

Motion planning and machine perception of surroundings are increasingly driving mine automation.







Digging for Efficiency

Proximity monitors, speed controllers, lane keeping assistants — such systems are commonplace on cars. Now they are finding applications in mining vehicles as well. The objectives: greater productivity, efficiency, and safety.

With herculean force, a massive electric rope shovel rips into the earth and removes over one hundred tons of material. The shovel then swings over to a waiting haul truck, carefully avoiding contact with the truck, opens its dipper door and empties its contents. A cloud of dust obscures the view as the dipper swings back to start the next cycle. After three loads the truck is full, departs, and is immediately replaced by another one. This sequence repeats itself every 90 seconds, 24 hours a day, 365 days a year.

Operating the world's largest excavators is not an easy job. An excavator weighs over 1,600 tons, and its massive components take time to respond; cab controls must be operated with foresight and precision. Pace is also important. The hard currency in an open pit mine is "cost per ton." In other words, efficiency is the top priority. However, in most cases, excavators' full potential is not being utilized. This was shown in a case study carried out by Siemens at a mine in Canada in 2012. A study of four electric rope shovels revealed that the average duty cycle was in fact too long. In addition, the shovel was often not optimally filled.

The result: additional loading cycles per truck, less extracted material per day, and higher costs. Yet it is difficult for shovel operators to judge at what height the dipper should be brought to the dump truck. To avoid incidental contact with the truck, operators err on the safe side and slow down and/or approach the truck at a greater height than necessary. Still, shovels do occasionally collide with trucks, resulting in damage and occasionally injury.

More precise operation through the use of fully automated vehicles is possible — but not likely to happen overnight. "The path to achieving fully automated movement patterns in a mine has to be followed step by step," says Dr. Robert Eidenberger, an engineer for robotic and autonomous systems at Siemens Corporate Technology in Munich. "And this path includes introducing the first assistance functions for vehicle operators."

Introducing Digital Assistance Systems. Eidenberger has been working on such systems for two years together with colleagues from Mobile Mining at Siemens' Drive Technologies unit in Alpharetta, Georgia. His work involves sensor technology, a machine's "perception" of its surroundings, and motion planning. Meanwhile, his U.S. colleagues focus on the drive control systems, motion execution, and the integration of all components into a complete system.

The aim of these efforts is to create systems analogous to those found in cars, so that drivers in mines are supported in making their work more efficient, safer, and more productive. One of the first packages to be designed for operators of large rope shovels is called "Swing to Truck / Return to Tuck, with collision avoidance." The system seamlessly controls the swing over to the haul truck, dumping, and the swing back to the starting position, where it hands control back to the operator. This package is now being tested by a leading manufacturer.

Optimal Movement Sequences. "We have been developing drive control systems for rope excavators for more than 30 years. What we lacked, however, was information about surroundings," says Daniel Robertson, product manager for software and autonomy at Mobile Mining. The group partnered with CT to develop a sensor-based perception system to continuously register the shovel's surroundings using pulses of infrared light. As the superstructure swivels around, a three-dimensional image of the environment is created that can detect the distance of an object relative to the shovel, be it a haul truck, a bulldozer, or a light vehicle. This module can recognize and identify areas that the shovel should not enter in order to avoid collisions. It can also perceive how full the loading bed is at any given moment and the profile of the heap, so it can estimate how much material has to be moved.

In addition to perception, a motion execution system was developed to "translate" calculated, optimized shovel trajectories into control inputs for the drive system. Drive Technologies specialists from Norcross, Georgia, implemented a position control interface to the excavator's existing drive control system, thereby replacing the input from operators. This system enables the shovel to automatically execute all movements along an optimally-trimmed motion path, which results in faster cycle times and more efficient movements.

In the future, assistance systems such as "Swing to Truck / Return to Tuck" could avoid delays and carry out movement patterns more quickly, saving energy. The case study showed that about four seconds could be saved per cycle. This would mean that the number of trucks each excavator could fill in a day would increase by 12 percent, thus raising productivity and reducing costs. Such systems could be on the market in as little as two years.

There is practically no limit to possible further development. But we are still far away from a fully autonomous mine — one that operates completely without human involvement. Until then there will be demand for skilled excavator operators — and operator assist features.

■ *Nicole Elflein*

Drive System for the World's Largest Dump Truck

How do you get the world's biggest truck rolling? BelAZ, a Belarusian vehicle manufacturer, came to Siemens with this question in 2011. BelAZ was looking for an electric drive for its new dump truck, which would weigh 360 metric tons unloaded. The new truck was to transport loads weighing up to 450 metric tons — equivalent to around 350 VW Golf cars or six fully loaded Airbus A320-200 planes — or about 25 percent more than the previous holder of the "world's biggest dump truck" record. Plans also called for the new truck to carry its load at a lower cost per ton of transported material and to have a top speed of 64 km/h when it empty. After all, companies that do underground and open-pit mining must not only adhere to environmental regulations but also consider the costs involved. That's why trucks used in this industry must be absolutely reliable and productive. Siemens has been developing drive systems for dump trucks for about 15 years, always with the goal of finding ways to make these giants of the mines more efficient. One example was the development of "trolley trucks," which get their electricity from overhead power lines. This innovation made it possible for such trucks to almost double their speed, even on steep ramps (see *Pictures of the Future,* Fall 2008, p. 20). But the challenge presented by BelAZ was something new for engineers at Siemens Drive Technologies. They were asked to develop an electric drive that would move a truck with a gross vehicle weight of up to 810 tons and would ensure that this truck was able to transport mined material quickly and reliably. In addition, the project was on a relatively tight schedule. The interval between the inquiry from the customer and the commissioning of the first truck was less than two years. In contrast to the previous model, the new truck was to be outfitted with eight tires, because each tire is designed to carry a load of only about 100 metric tons. With this in mind, Siemens' traction-drive experts in Nuremberg settled on developing a reliable and powerful all-wheel-drive system that uses four electric motors. A tried and tested drive system served as the model for the new system. The engineers also developed a new control solution. All of the electric drive's components came from Siemens. This ensured that all the elements would work together perfectly. The all-wheel-drive configuration provided the engineers with new possibilities, such as dynamic power distribution between the truck's two axles. Moreover, if one of the electric motors were to fail, the truck would still have emergency drive capability, meaning that it could be driven to a workshop under its own power — in other words, it doesn't have to be towed or left to block a ramp, for example. The system uses two 16-cylinder diesel engines, each with an output of around 1,700 kW. Together, they provide the energy that the electric drive requires. The truck was unveiled to the public in October 2013. It is over 20 meters long, almost ten meters wide, and around eight meters tall. Its all-wheel drive and four-wheel hydraulic steering ensure that the tires, which are around four meters tall, don't get stuck in rough terrain. The truck is now being tested at an open-pit coal mine in Siberia, and sales of the vehicle are expected to begin later this year. After that, it will be used primarily to transport coal and iron ore-bearing rocks. *Nicole Elflein*

Imagine driving to an appointment at night without the benefit of streetlights, signs, people who can help, or even a windshield. All you have is two displays to the side of the steering wheel: One shows a street map; the other shows where you are. Wouldn't things be a lot simpler if the images could be combined? This is roughly the challenge confronted by cardiologists when performing what are known as "interventional" procedures, such as implantation of a stent or valve by means of a remotely controlled catheter.

During such procedures a nearby monitor typically displays a high resolution pre-operative computed tomography (CT) image of the vascular anatomy while a separate X-ray fluoroscopy image produced in the interventional suite itself displays the real-time location of the catheter tip.

"Surgeons are skilled in putting these images together in their minds," says Daphne Yu, who heads the Image Visualization Lab at Siemens Corporate Technology in Princeton, New Jersey. "But by using advanced visualization, we can put the pictures together for them."

The big picture, however, is much broader than that. Indeed, what Yu and her colleagues at Corporate Technology and at Siemens' vast Healthcare Sector have in mind is nothing less than a vision of tomorrow's operating and interventional environments in which all modalities are ergonomically integrated.

Learning software identifies and separates organs in pre-operative CT and MR scans, making it possible to integrate them with real-time images generated in the OR. Together, these data sets provide a navigational context for a range of cardiac procedures. Researcher are learning how to stream these real-time images to a wireless tablet.

How Data Fusion will Transform Tomorrow's Operating Room

Today's operating rooms and interventional suites are cluttered with cables and diagnostic systems that compete for attention. Researchers at Siemens Corporate Technology envision an environment in which a portable, wireless display integrates all image data into a single, real-time information overview, including analytics, virtual consultation, and simulations.

Such modalities include, for instance, live endoscopic images, ultrasound, real-time CT, fluoroscopy, electrophysiology (used in neutralizing cardiac tissues responsible for arrhythmias), and, above all, 3-D pre-operative CT or magnetic resonance (MR) image sets. The latter are particularly important because they can provide the navigational landscape into which all other modalities will eventually be integrated.

A Roadmap Takes Shape. With this vision of tomorrow's integrated treatment environment in mind, researchers at Siemens Corporate Technology have developed learning-based software that can identify and segment (separate from its surroundings) any organ in any digital medical image, regardless of occlusions, angle of view, imaging modality, or pathology (see *Pictures of the Future,* Fall 2011, page 57).

An example of this capability is a heart model segmentation software that automatically separates the heart from a 3-D CT or MR image set. When used in combination with live fluoroscopy, segmented heart models can be used, for instance, to locate the exact areas on the heart's surface to be ablated in order to neutralize arrhythmia-causing tissues.

In addition, at the U.S. National Institutes of Health (NIH) in Bethesda, Maryland, live image-model fusion software developed by Siemens Corporate Technology in cooperation with Siemens Healthcare has been used experimentally to help guide an artificial valve to its target in a pig's heart. "This fusion of heart models and live images provides the landmarks that help physicians identify exactly where a catheter is located in real time," says Yu. "It is a promising example of the power of image fusion in the interventional suite and operating room."

Working along similar lines, Razvan Ionasec, PhD, a specialist in machine learning applications for medical imaging at Siemens Imaging & Therapy Systems Division in Forcheim, Germany, is combining pre-operative 3-D CT images with 2-D X-ray video images generated in the operating room itself by a Siemens "C-arm" CT scanner.

"What typically happens," he explains "is that before an operation you have a lot of high-resolution equipment and time to produce images. But what you want is to make this pre-op information available in the operating room, where time is short and imaging power is limited. To bridge this gap, the pre-op information is mapped to the fluoroscopy data. As a result, all of a sudden, you have real time motion information — something you would never be able to get from fluoroscopy alone."

The integration of modalities is already paying off. A technology described in *Pictures of the Future* Fall 2010 (page 79) for the interventional placement of aortic valves has recently been bolstered by the addition of pre-operative CT data. The resulting product, syngo.CT Valve Pilot™, not only automatically segments the aortic valve and related structures from a CT scan, but provides measurements, such as the radius of the valve, which are essential for planning and conducting an intervention.

Meanwhile, another technology, which is known as "eSieFusion™ imaging" (see *Pictures of the Future,* Fall 2013, page 37), overlays live ultrasound images on previously-acquired 3-D CT and MR image sets. The technology, which is now available on Siemens' ACUSON S3000™ ultrasound systems, is used to guide a biopsy needle to its

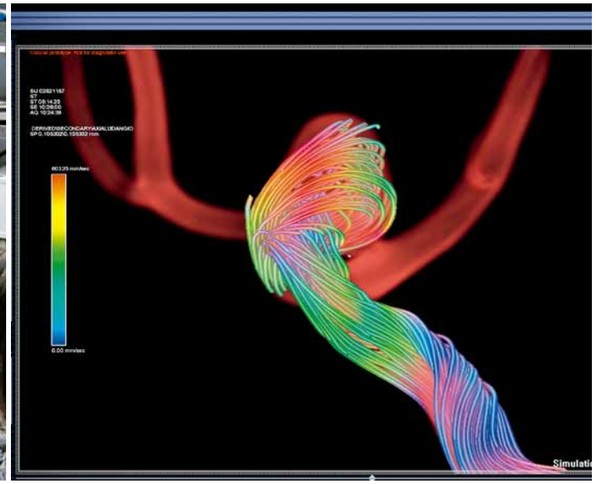
target with enhanced confidence. Ultrasound will eventually also be integrated with CT and X-ray images to support the placement of aortic valves, says Ionasec.

Data Fusion Goes Mobile In addition to the integration of multiple clinical modalities, researchers at Siemens Corporate Technology have their sights set on making such images available wherever they are needed in real time. "Rather than having a huge screen with separate views of the area to be treated," says Yu, "we have come to the conclusion that it is more practical and comfortable to have a single, integrated image that is portable." Such an image could be available on a stand-mounted tablet or could even appear in a head-mounted device. The latter would support the integration of visual and mental activity with hand-eye coordination and might even be used in an augmented reality context, thus allowing a surgeon to superimpose diagnostic information on his / her actual field of view.

On-the-spot simulation functions could provide advice as to the best spot to clip an aneurysm.

To realize this vision, Siemens researchers are developing techniques to promote extremely fast visualization. For instance, a team led by Dr. Andreas Hutter at Siemens Corporate Technology is focusing on ways to tailor streaming and video compression to medical applications, while others are working with chip manufacturers to minimize the computing and power demands needed to process images. "These efforts are starting to pay off," says Yu. "They have made it possible for us to stream real-time images to a tablet using standard Ethernet technology."

The need for achieving a virtually imperceptible delay is clear. "If you are pushing a needle or a catheter through a patient's anatomy you need to have instant feedback," says Yu. "For instance, if you are doing a procedure in which angiography is involved, our scanner works super fast to produce each image and encode it. The images must then be streamed to the viewing device, decoded and rendered." Naturally, processing demands are even higher as additional imaging modalities are added and fused. Nevertheless, whatever delay this adds will probably not be noticeable. With eSieFusion imaging, for instance, initial registration of CT and ultrasound images requires three seconds, after which any two images can be fused in real time.



The U.S. National Institutes of Health have used Siemens' live image-model fusion software in an experimental procedure to place an artificial valve in a pig's heart. Right: Real-time simulation of blood flow.

Adding Expert Systems to the Picture. Nor will multimodality data fusion in tomorrow's operating rooms and interventional suites be limited to images. "Our vision is that all the information that's needed will be available when and where it is needed," says Yu. "In addition to pre-op and real-time image fusion from multiple sources, we will have live patient monitoring, such as heart rate and blood pressure." Further down the road, demographic data and expert systems built on thousands of similar cases could be brought to bear on individual procedures, thus opening the door to virtual consultation functions and the analysis of alternatives.

On-the-spot simulation functions might, for instance, provide advice as to the best spot to clip an aneurysm based on real-time computational fluid dynamics. Virtual angiography, individualized anesthesia and drug dose interactions — all could be simulated during a procedure and then tracked as administered to refine underlying algorithms.

Last but not least, data fusion can be expected to save money. "It will provide a method for automatically recording procedures," says Yu; "this will support effective systems for reimbursement, and can be exploited by learning systems to further refine treatments."

For all its potential, multimodality data fusion will need to overcome many challenges. Software from different systems will need to become far more interoperable, standards for everything from image quality to transmission speed will need to be developed, and a virtually unlimited appetite for bandwidth will demand ever-increasing processing power and energy efficiency. "It is still early days for real-time data fusion," says Yu; "but when you add up everything that is happening in this field, you see that we are in the process of creating an ecosystem that will transform the way we plan, perform, document, and learn from a vast range of treatments." ■ *Arthur F. Pease*

The World's Biggest Eye

The largest observatory on Earth is actually an array of 66 radio telescopes. Located deep in the Chilean desert and scattered over a huge area, the telescopes' antennas peer into the depths of the universe. But it's Siemens' technology that keeps the facility's lights shining.

Snow-covered mountain peaks rise up in the distance. Cacti as tall as a man line the dirt road. "It's too dry here for other plants and for most animals," explains Rodrigo Gutierrez. "Once in a while we see a fox, but it can barely find enough to eat." Gutierrez works at the ALMA (Atacama Large Millimeter/submillimeter Array) observatory. His work regularly requires him to climb to heights of well over 5,000 meters. Gutierrez' job is to ensure the safety of his colleagues, who maintain and service 66 telescopes. Each unit is as big as a house and costs around US$30 million to build.

The telescopes turn at night, when only the stars stare down at the Chilean desert, moving millimeter by millimeter with a precision equal to that of a Swiss watch. Together, they form the world's biggest eye on the sky. The data they record is processed into a complete image by a supercomputer that acts as the observatory's nervous system. Whereas the human eye captures light at wavelengths of between 0.38 and 0.78 micrometers, the ALMA telescopes can detect millimeter waves, which have a length of 0.3 to 9.6 millimeters. Unlike visible light waves, these waves are very good at penetrating clouds of gas and dust, such as those that surround the places where stars are born.

The telescopes are arranged in an array with a circumference of 16 kilometers. They observe the universe — and in the processs, by capturing infrared light that has journeyed for billions of light-years to reach the Chilean desert, they essentially travel back through

ALMA's 66 telescopes in the Atacama desert represent an investment of about $30 million each.

time. Researchers use the resulting data to draw conclusions regarding the distribution of gases at the dawn of our universe. Bygone galaxies that were previously unknown have been discovered this way. Scientists have also used ALMA to identify small organic sugar molecules that provide us with a clue concerning the nature of primordial molecules of life in the cosmos. Paradoxically, ALMA's high-tech devices are located in one of the regions of Earth that is least hospitable to life: at altitudes of up to 5,600 meters in the desolate Atacama Desert near the Bolivian border. Still, the location is perfect for stargazing. In general, three things are important to astronomers. They want their telescopes to be located on top of tall mountains, and they want this environment to be dry and dark. Air and water molecules in the lower layers of the atmosphere distort observations, and man-made light sources obstruct the view of conventional telescopes — though not of radio telescopes like those at ALMA. All in all, few places are as suitable for an observatory as the Chilean desert.

By capturing infrared light that has journeyed billions of light years, ALMA essentially travels back through time.

Deep Chill. ALMA is a two-hour drive from the nearest city, and it's located in one of the world's driest deserts. The observatory is said to be the second-highest building on Earth (the highest is said to be a train station in Tibet). "The air up here is so thin that our brains don't always function perfectly," Gutierrez says. "The lack of oxygen causes minor blackouts. You need to be careful, because even the tiniest mistake up here can cause millions of dollars' worth of damage to the telescopes. That's why my colleagues put oxygen tubes in their noses when they have to perform complicated tasks." Gutierrez is all bundled up. He has to be, because temperatures at night can fall to as low as -20 degrees Celsius. He also wears sunglasses and a hat to protect him from the high levels of UV radiation here, which can burn uncovered skin in just a few minutes.

International research institutes have invested about $1.3 billion in ALMA. In return, they have received the world's most precise observatory — the biggest eye on earth. If ALMA were an optical telescope used for looking at objects on Earth, it would be possible to see the dimples on a golf ball from a distance of 15 kilometers. As some researchers point out, in terms of its precision, ALMA amounts to a revolution — one that is comparable to the difference between the naked eye and the first telescope.

Chile is one of the world's most important locations for observing the heavens. The many observatories that have located there are a godsend for the country's universities. And with more and more telescopes being built there, scientists estimate that by 2020 it will be home to around 20 percent of the entire surface area of all the world's telescopes — many of which, such as those at ALMA with their 12 meter diameters — are very large.

With so many telescopes there is a tremendous need for experienced personnel and associated facilities. "We're waiting for a hotel with 170 beds to be completed; until then we're sleeping in containers," Gutierrez explains. In the middle of a container village — at an elevation of 2,900 meters — is the camp's canteen. A group of Japanese researchers is sitting here; they don't seem thrilled by the food on their plates. They'd much rather have their home cuisine again; it's been weeks since they've eaten sushi. Meanwhile, an Italian scientist says he would give anything for some pasta al dente.

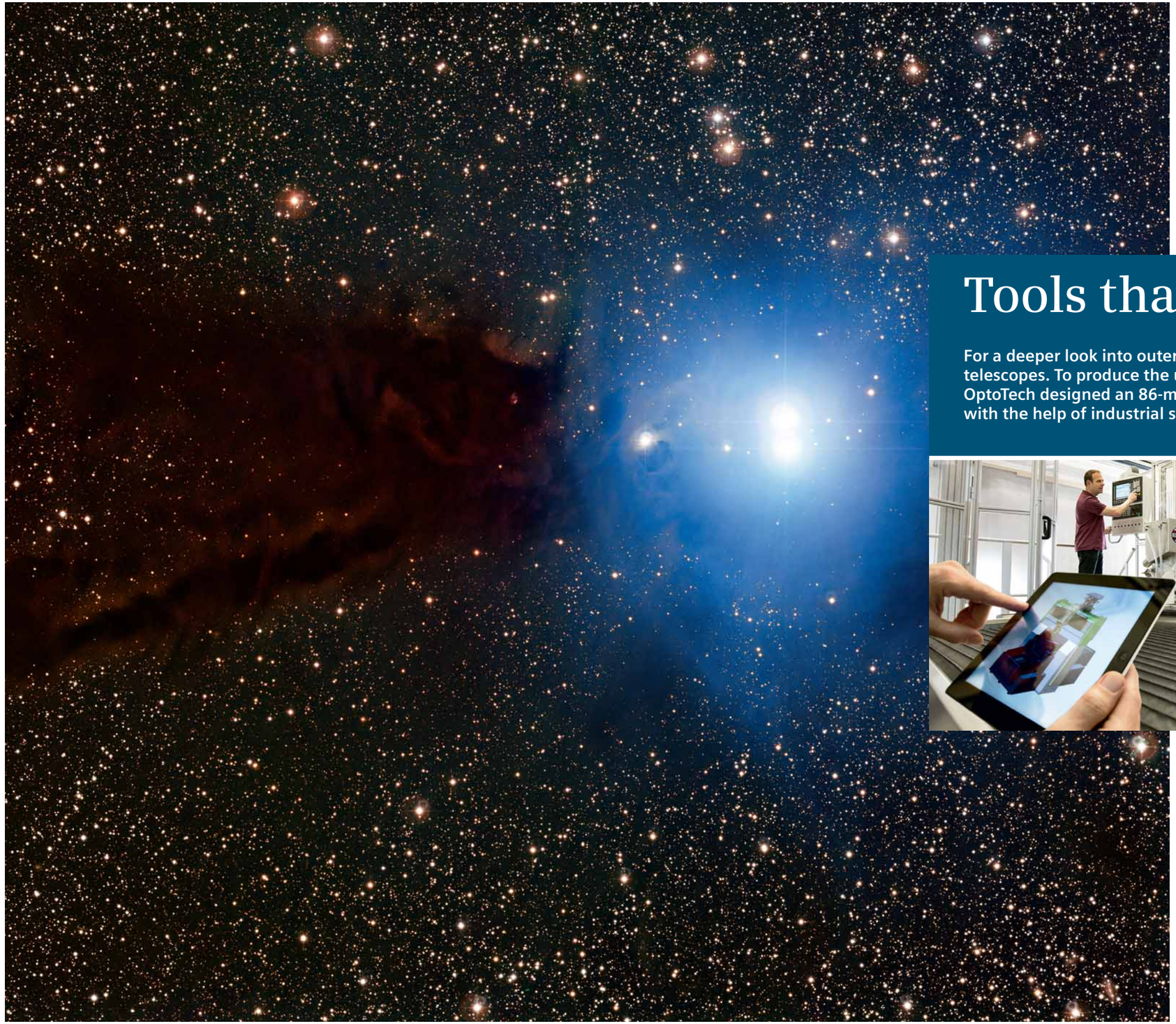
Way up There. Regardlesss of their size, all advanced observatories need electricity, and a lot of it. They need it not only to power rotation motors, but also their lights and climate control systems. When ALMA was opened, electricity for the camp, the telescopes, and the supercomputer was supplied by diesel generators. However, these units were loud and inefficient. In 2012, three small gas turbines went on line.

Oscar Galvez Iglesias is responsible for making sure ALMA's stargazers never run out of power. "We now generate around two megawatts of electricity," he explains. "The observatory is expanding, so we'll soon need to increase capacity by 50 percent." That's because at an altitude of 5,000 meters even the air conditioners require more energy to cool the central computer than they would need at lower elevations. That's because the air is so thin at this altitude.

A small power plant situated slightly above the container village is equipped with Siemens circuit breakers, protection and monitoring systems for medium-voltage facilities, and control cabinets. Simatic control panels ensure easy operation of all equipment. And if an accident were to occur nonetheless, a Siemens fire protection system would ensure that any blaze would be detected and controlled immediately.

A little further uphill from the plant, at 5,100 meters, Siemens has built a substation to supply the telescopes with electricity. "I'm proud of what I do," says Iglesias. "ALMA is the world's biggest observatory, and I make sure that the lights stay on." The day is coming to an end, and Iglesias is about to head for the canteen. He stops for a moment and looks up at the sky. As he leans his head back, he sees how the pale baby-blue color of the horizon gradually darkens into the deep blackness of outer space. In a few hours, only the dark universe will be looking down at the earth. The stars will then tell Iglesias their story of infinity — until they themselves one day flicker out. ■ *Andreas Kleinschmidt*

Siemens technology ensures a secure power supply as well as top fire protection.



Tools that Look through Time

For a deeper look into outer space, astronomers need a new generation of optical telescopes. To produce the ultra-precise large-scale mirrors needed for these instruments, OptoTech designed an 86-metric-ton special-purpose machine. The machine was created with the help of industrial software and control-and-automation technology from Siemens.

Siemens software simulated and developed a machine (left, below) that produces huge mirrors for high-performance telescopes.

The sun is about 150 million kilometers away from the Earth. For astronomers, that means it's practically right outside the front door, since light needs only 8.3 minutes to travel such a distance. But astronomers want to look much farther. In fact, in the future, they want to observe galaxies as far as 13 billion light-years away — thus looking back almost to the time of the big bang.

A new generation of large telescopes is expected to make this possible. The main challenge here is to produce the large numbers of extremely precise mirrors that will be needed. The primary mirror of one such telescope already contains approximately 800 hexagonal mirror elements, each with a diameter of about 1.5 meters and a thickness of 50 millimeters. To be able to capture and focus the dim light from space, the dimensions of every element of these mirrors must be accurate to within just a few nanometers.

In the Bavarian town of Teisnach, engineers are working hard to solve this problem. In 2012, after three years of preparation, the largest and most modern precision-optics machine in the world began trial operation here on the Technology Campus of the Deggendorf Institute of Technology.

The UPG 2000 CNC (computer numerically controlled) provides the highest precision when it comes to grinding, lapping, and polishing astronomical optics — all in a single machine. It was designed and built by OptoTech Optikmaschinen GmbH, a global market leader for optics machines used in everything from super-micro optics to micro and macro-optics, as well as planar and eyeglass optics.

"We developed this general-purpose machine specifically for the production of mirrors with diameters of up to two meters and for other large optical components," says Jochen Franz, head of the Design department at OptoTech in Wettenberg, about an hour north of Frankfurt, Germany. The objective of the tests in Teisnach is to achieve a manufacturing accuracy of 30 nanometers, or roughly one thousandth of the diameter of a fine human hair.

No Mistakes Allowed. On the UPG 2000 CNC itself, however, everything is big. It weighs in at 86 metric tons, the granite block on which it rests weighs 40-tons, the mirrors it produces are huge, and likewise the challenge posed by its manufacture is substantial. In short, no errors can be tolerated — no expensive prototypes that don't work correctly, no glitches that hamper operations, and definitely no mirrors with precision problems.

A 340-million-pixel image of the central regions of our Milky Way.

Despite the pioneering work that was required, OptoTech developed its machine in just 1.5 years in collaboration with Siemens, which contributed a substantial amount of its own industrial software and control and automation technology.

To pare down development time and meet the huge demand for astronomical optics without delay, OptoTech experts relied on innovative industrial software that links the virtual and real production worlds within the framework of a product lifecycle management system (PLM).

With this in mind, the company turned to Siemens' NX, an integrated PLM software solution. "In addition to product design, 3-D modeling, and documentation, this software enables you to perform multidisciplinary calculations. These computations link various aspects of rigidity and flow calculations, heat transfer, and kinematic processes to produce results that provide the most accurate possible simulation of reality," says Peter Scheller, Marketing Director for NX at Siemens PLM Software in Germany.

"NX and the integrated development environment accelerate development, design, and production and thus significantly shorten time to market," he adds.

At OptoTech, design engineers first created a virtual 3-D design of their future machine. At that stage, the software already indicated whether the overall design and the elements it would use would work properly, because all of the actual properties of the Sinumerik control and Sinamics-type Siemens drive were fed into the design via NX. A team from Siemens Mechatronic Support then analyzed, simulated, and optimized the virtual machine's design.

Virtual Prototype. Thanks to this virtual design process, expensive physical prototypes are becoming a thing of the past. So too is the time-consuming parallel computation that used to be necessary to find out whether a design will be structurally sound once built. Scheller explains: "Thanks to the CAM module for production simulation, it was even possible for OptoTech to simulate the exact production run for a single mirror. The software for the virtual machinery moves the digitally-designed machine in realistic ways. So it's possible to put it into service virtually, as it were, early on in the process."

And the benefits of NX-based development are evident after the real startup as well. "The leading PLM platform today is called Teamcenter. NX is integrated into this platform more deeply than any other solution," says Scheller. "All the data from the design phase, acceptance by the customer, and subsequent maintenance can be saved and is available at all times. That's a huge advantage when there are maintenance activities or difficulties with a machine."

"NX accelerates design and development and thus significantly shortens time to market."

The benefits of this industrial software can be particularly clearly seen in the case of new solutions like the UPG 2000 CNC. For experts at OptoTech, it was clear that they could achieve the manufacturing quality demanded by the market only with a completely new, complex combination machine. "Time and precision are always lost in the process of moving a piece from one machine to another and resetting it. It was important to avoid that," says OptoTech founder and Managing Director Roland Mandler. "And so we integrated all the necessary processing steps into our Sinumerik-controlled ultra-precision grinding and polishing machine."

Integrated Drive Technologies. OptoTech relies on Siemens for drive technology too. The reason, according to Robert Neuhauser, CEO of Siemens' Motion Control business unit, lies in the integrative approach pursued by Siemens. "In a complex project like this one, integrated drive technologies offer major advantages," he says.

These technologies guarantee the smooth interaction and optimal dimensioning of all sub-systems and components, from the converter to the motor and the couplings of the gear system. They also assure vertical integration extending all the way to the control level as well as customer support throughout the entire lifecycle of a machine — from simulation to engineering to servicing during regular operation.

OptoTech was won over by this package of benefits. "The fact that we had a good, long-standing relationship played a role here, and so did the development assistance we received from the Mechatronic Support specialists," says OptoTech Design Director Jochen Franz. "But the technical factors were decisive: No other supplier of control technology has a premium CNC system that is openly scalable and modular in the way the Siemens product is."

Computerized Numerical Control refers to the electronic control and regulation of machine tools or CNC machines. Thanks to their electronic control technology, CNC machines can automatically produce even complex workpieces and do so with a speed and precision far superior to those that are possible with mechanically controlled machines. According to Franz, other advantages of Siemens CNC systems are their ability to adapt straightforwardly to customer-specific user interfaces and be accessed remotely for maintenance (p. 84). With these features, OptoTech can quickly support its customers around the world at all times.

The machine that resulted from the OptoTech-Siemens partnership is now in the possession of Ifaso GmbH (a company whose name is an acronym meaning "integrated production of aspherical optics"). OptoTech established Ifaso together with the Deggendorf Institute of Technology in order to market the new machine. The global market for this unique instrument is expected to grow dramatically. Inquiries have already been made by China, Russia, and India; all of which have space programs. OptoTech Managing Director Mandler is certain that the UPG 2000 CNC will generate interest in other sectors as well, such as semiconductor lithography.

■ *Mirjam Müller*

Approaching Reality through the Virtual World

With nine million licensed seats, Siemens is one of the world's leading suppliers of product lifecycle management (PLM) software and associated services. In its NX software suite, the company offers a solution for flexible, efficient, rapid, and high-quality product development and manufacturing. Computer Aided Design, Computer Aided Manufacturing, and Computer Aided Engineering (CAD/ CAM/CAE) are all integrated into NX. The benefits of this combination can be seen in 3-D modeling and documentation, as well as in the multi-disciplinary calculation of structural, kinematic, thermal, fluid-mechanical, and multi-physical processes.

In Brief

The steady shift from the physical to the digital world is touching almost every aspect of life. Analog information is being digitized — i.e. turned into binary code. This development has endless ramifications, one of which is the growing availability of detailed, real-time information in almost every sector. (pp. 77, 97)

Manufacturing. Products and factories are being simulated long before their physical counterparts exist, and the data this generates is being used in the planning and design of industrial facilities and even the world's biggest telescopes. Building sites, once the domain of the analog world, can be digitally monitored and optimized. Aerial photos taken by drones can be used to continually compute 3-D models — such as the new Aspern section of Vienna, Austria. (pp. 92, 99, 111)

Critics of digitization see a threat to privacy. Proponents see opportunities for expanding democratic participation. According to Vasilis Koulolias, founder of eGovLab, citizens could be involved in city planning much sooner. MIT professor Erik Brynjolfsson predicts that software will replace more and more jobs even as it brings benefits to ever more people. Meanwhile, avatars are being used to model human activity in dangerous work environments in order to reduce risk to humans. (pp. 82, 90, 100)

Multimodal imaging will transform interventional treatment. Siemens researchers envision treatment environments in which a portable, wireless display integrates all image data and associated information into a single, real-time information overview. (p.104)

Countless traffic lights, gas turbines and computer tomographs around the world are being remotely monitored and updated to prevent shutdowns. Apps tell us the best way to get to our destinations as well as how to purchase tickets and parking passes. (p. 81, 84)

Software and the cloud are replacing centralized data storage and processing at individual physical locations, such as a company's hard drives and servers. The cloud is virtually unlimited and can be expanded quickly as needed. In combination with new computer programs, the cloud opens up opportunities for business models whose variety is only hinted at today. (p. 79)

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LINKS:

BITKOM, Federal Association for IT, Telecommunications and New Media:
www.bitkom.org (statistics, markets, sector barometer)

Study: "The Digital Universe in 2020":
http://idcdocserv.com/1414

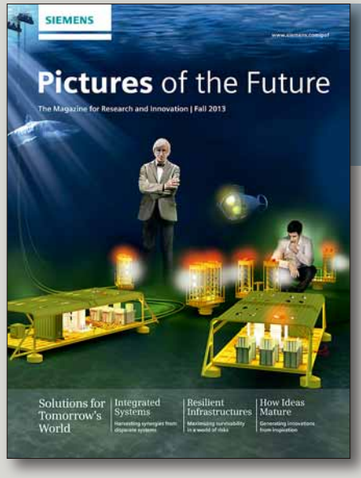
Studies: "Navigating the Digital Future" and "Global Innovation 1000":
www.booz.com/innovation1000

Siemens PLM Software:
www.plm.automation.siemens.com

eGovernment (eGovLab):
www.egovlab.eu

MIT Center for Digital Business:
ebusiness.mit.edu

Bavarian State Library:
www.bsb-muenchen.de



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PoF: More Digital, More Interactive

Reading habits are changing. A Google study from 2012 shows that in the U.S. nine out of ten activities that involve the use of media already take place in front of a display, be it part of a smartphone, tablet, PC or TV. Newspapers and magazines in paper form are being read less and less. *Pictures of the Future* has always had the objective of not only reporting on future trends but also helping to define them. Therefore, starting from fall 2014, we will launch a high-end online version of *Pictures of the Future* that not only features new articles, images, videos, and animated graphics weekly, but also involves you, our readers, and your wishes and suggestions to a much greater extent than is possible with printed media. This involvement will begin with the selection of topics. Which subjects, from digital technologies and software to energy efficiency, industry and manufacturing, infrastructures and finance, health and people, mobility and drives, and research and development, would you most like us to report on?
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