Solutions for Tomorrow’s World

The Future of Oil and Gas
Higher efficiency through electrification and automation

Tomorrow’s Grid Systems
Innovations for distributed energy supplies

The Future of Manufacturing
3D printing, virtual worlds, and digital twins
The Future Is Digital

Siegfried Russwurm, Member of the Managing Board of Siemens AG, Chief Technology Officer, and Head of Corporate Technology, outlines his vision of our digital future, how the trends that are driving it will transform our lives, and how those trends are already transforming Siemens’ Pictures of the Future magazine.

Which technology trends will be dominant in the decades ahead? The world’s energy supply must be placed on a new and sustainable foundation. Electrical power that can be generated, transmitted, and consumed very efficiently will become a comprehensive energy carrier to a far greater extent than it is today. Global energy demand is growing three times as fast as the world’s population. What’s more, a new era of automation and digital services is dawning. In the coming 30 years the computing power, storage capacity, and data transmission rates of microchips will increase a thousandfold — and digital machines will become multifaceted assistants in daily life and the workplace. By 2050 almost as many people will be living in cities as are alive in the world today — and for the first time in history, there will be more seniors than children and young people.

Electrification, automation, digitalization, urban infrastructures, and new solutions for healthcare systems — in all of these areas Siemens occupies leading market positions and is forging ahead with research and development on a massive scale. We are seeing the most dynamic developments in businesses that provide digital services, which are posting growth rates of seven to nine percent annually. Today data is the raw material of the global economy — and, in contrast to other raw materials, the volume of data is continuously increasing. According to analysts at International Data Corporation, the volume of digital data stored worldwide is expected to increase by a factor of 40 to 50 between 2010 and 2020. Today more data is generated hourly around the world than the amount recorded in books throughout history. The transformation of data into digital services is causing massive changes in economic value chains. For instance, a person using a tablet not only can read magazines and newspapers on it, but also alter a robot’s parameters or monitor an entire power plant.

From Big Data to Smart Data. Nonetheless, data does not embody any intrinsic value. It’s not the volume but the content of the data that is crucial. The important thing is not big data — it’s smart data! For example, in a large gas turbine hundreds of sensors measure temperatures, pressures, currents, and the compositions of gases. A person who analyzes these values correctly can give the operator of the power plant recommendations on how to adjust the plant so as to make it more efficient and reduce its pollutant emissions. In order to do so, such a person must have information about the equipment and about how it performs in operation, as well as the relevant algorithms to evaluate the data. This results in genuine added value for the customer, who can then save energy, operate a facility in a more environmentally friendly manner, reduce costs, speed up processes, and increase the plant’s reliability. The use of smart data enables Siemens to develop new solutions in all of its areas of operation: the networking of transportation systems, smart grids, and virtual power plants; the digital factory with highly automated and flexible production facilities; and the computer-assisted assessment of healthcare data. Exciting challenges lie before us in all of these areas, and meeting these challenges will be a worthwhile effort. In view of this, we at Siemens have made it one of our major goals to forge ahead with the digital transformation throughout the Group so that we can generate innovations that deliver significant benefits to our customers.

New Online Magazine. Since 2001, Siemens has had a tradition of reporting on research, development, and the trends of the world of tomorrow in its magazine Pictures of the Future. We are continuing this tradition, but from now on we will primarily do so in a high-quality online magazine — with all the advantages that the digital transformation offers in the world of media. You can subscribe to the magazine as a whole or to individual sections. Here you will find dossiers that compile all of the relevant information about the most important issues facing us — in future scenarios, articles about trends, reports, interviews, and economic analyses. These articles will be supplemented by videos and animated infographics, photo galleries, and interactive 360-degree features. With the current “Best of Pictures of the Future,” we would like to spark your curiosity regarding the latest articles from our digital edition. Join us as we enter the digital world — in research and in Pof Digital. www.siemens.com/pof
### Tailor-Made Locomotives

Until recently, rail operators that needed electric locomotives to handle changing needs were faced with three to four-year delivery times and long approval processes for every minor change. Siemens' new, modular system for its Vertex all-purpose locomotive has radically changed the picture. This means that Siemens can produce frames, drivers' cabs, vehicle bodies, chassis, and bogies for stockpiling on a continuous basis. Each component has a specific area within the locomotive's machinery compartment, which is individually equipped as soon as a customer places an order. Customers can change orders as little as six months before delivery. Not only can they change train control systems and extras such as rearview cameras and country-specific pantographs, they can also alter basic features such as the power system and the locomotive's output.

### Siemens Powers the World's Strongest Truck

Guinness World Records has crowned the BelAZ-75710 dump truck as the world's most powerful truck. One of these gigantic vehicles is able to transport more than 500 metric tons of material — equivalent to seven fully fueled and loaded Airbus A320-200 planes. The truck is driven by four 1,200 kW electric motors from Siemens. 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 in order to propel the giant tires. The truck's development was completed in a comparatively short time. It took less than two years from initial order to commissioning. The vehicle is over 20 meters long, almost ten meters wide, around eight meters tall, and has a top speed of 64 km/h. Its all-wheel drive and four-wheel hydraulic steering ensure that the tires, which are around four meters in height, don't get stuck in rough terrain. The truck is primarily used in Siberia to transport coal and iron ore-bearing rocks in open-cast mining.

### Keeping an Eye on the New Gotthard Tunnel

The new Gotthard Base Tunnel — the longest railroad tunnel in the world — which is currently being built between Erstfeld and Bodio in Switzerland, has concluded its first test phase. Control technology from Siemens located in two Tunnel Control Centers (TCCs) monitors all of the facility's electromechanical systems. The 57-kilometer tunnel benefits from sensors, control electronics, and monitoring facilities that are connected with the TTCs by fiber optics. Starting in mid 2016, passenger and freight trains will be able to travel through the tunnel, which passes more than 2,000 meters below the Gotthard massif, much faster than they could through the old Gotthard tunnel.

### Data Transfers

The amount of data generated in all areas of life is growing at an incredibly fast pace. In the future the question is how to be able to wirelessly transmit and store such high data volumes even more quickly and securely. That's why Siemens experts are analyzing multichannel systems. Today's laptops are equipped with only one antenna, but multichannel systems are based on various antennas that exchange electrical signals simultaneously. Each of these antennas consists of up to 100 small antennas. They assure data connections with very low losses and extremely low resistance. Siemens researchers are investigating how radar beams, angle measurements in radar systems, and RFID chips can benefit from multichannel systems.

### New Software Identifies and Flattens Bones

Trained on thousands of annotated pictures, new medical image analysis software can instantly identify a patient's rib cage in a computed tomography (CT) scan, separate it from other anatomical elements, flatten it for easy review by a radiologist (picture), and automatically label each of the 24 ribs. This learning-based technology cuts review time in half, reduces errors, and significantly improves the chances of detecting cracks and metastatic cancers. Once trained on images of, say, the liver, each one of which has been annotated by experts, such software has essentially memorized the three-dimensional shape and appearance of a target anatomy and can therefore generalize to the extent that it can identify and segment (separate from its surroundings) that target in any medical image, regardless of occlusions, angle of view, imaging modality, or pathology. And the same is true for a rapidly-growing number of anatomical entities throughout the body, from organs and bones to the outlines of a fetus or a lesion. The software, which was developed in cooperation with the Siemens' Computed Tomography and Syngo business units, has made it possible to automatically flatten the ribs, thus substantially accelerating the review process. The software is already being used in 147 hospitals or imaging labs in 63 countries.

### Tomorrow's Data Transfers

The amount of data generated in all areas of life is growing at an incredibly fast pace. In the future the question is how to be able to wirelessly transmit and store such high data volumes even more quickly and securely. That's why Siemens experts are analyzing multichannel systems. Today's laptops are equipped with only one antenna, but multichannel systems are based on various antennas that exchange electrical signals simultaneously. Each of these antennas consists of up to 100 small antennas. They assure data connections with very low losses and extremely low resistance. Siemens researchers are investigating how radar beams, angle measurements in radar systems, and RFID chips can benefit from multichannel systems.

### Twice as Efficient as Diesel

For the first time ever, trucks will be able to drive on a public highway using current collectors. This is being made possible thanks to overhead cables that Siemens is installing for electric and hybrid trucks in Carson, California. Up to four test trucks will be supplied with electricity in both directions, enabling them too travel along the two-mile eHighway system without producing any emissions. The technology will be tested in practice until mid-2016. Siemens is running the project in cooperation with Volvo Group's Mack Trucks subsidiary and conversion specialist Transpower. The eHighway system was developed by Siemens for heavily used truck shuttle routes and encompasses overhead cables for roads as well as electric or hybrid trucks fitted with intelligent current collectors. Sensors on the vehicles' roofs recognize whether there is an overhead cable and can automatically connect or disconnect the truck. With an efficiency of around 80 percent, the eHighway system is about twice as efficient as a diesel truck.
A System that Could Help Cities Rethink Parking

Siemens has developed a system that will help drivers find parking spots quickly and without stress. The system will rely on radar sensors integrated into streetlights. The sensors will transfer data regarding empty spaces to a control center that will inform drivers in real time.

On average, finding a parking place in a German city requires about 4.5 kilometers of extra driving. According to the German Federal Motor Transport Authority, that means that a typical car emitting around 140 grams of CO2 per kilometer will generate at least 630 grams of unnecessary CO2 in the process of looking for a parking space — and significantly more in stop-and-go traffic.

Thirty Percent of Traffic. A scarcity of parking spaces has many negative consequences: exhaust fumes and particulates in the air, noise, and the frazzled nerves of frustrated drivers. “Depending on a city’s size, vehicles looking for parking spots account for about 30 percent of its total traffic volume,” says Marcus Zwick, who heads a project that is developing smart parking space monitoring in Siemens’ Mobility Division.

That’s why Zwick and several of his colleagues have been working since October 2013 to develop new approaches to the problem. His solution is called Advanced Parking Management. In this concept, radar sensors integrated into streetlights or mounted on buildings could continuously monitor parking areas throughout a city and send information about parking space occupancy to a software system. Urban authorities would collect this information and pass it along to app operators in real time. Thus every road user would know the locations of empty parking spaces via a terminal such as a smartphone, tablet or navigation device.

Radar Sensors to the Rescue. Siemens specialists opted to use radar-based sensors in the project, which is being supported by Germany’s Federal Ministry for the Environment. “It’s true that radar sensors have a lower resolution than conventional surveillance cameras, but they offer other advantages,” Zwick says. For example, because of their low resolution, they can record only schematic images. “The individual road users’ right to privacy is safeguarded,” he explains. What’s more, radar sensors are much less sensitive to fog, rain, changing light conditions, and winter weather, and they are more economical than ground sensors.

Identifying Empty Spaces. The principle underlying the process is simple. A sensor’s circuit board, which is about the size of an adult’s fist, transmits microwaves at a predefined space, and the microwaves bounce back to the sensor when they hit an obstacle. The sensor then uses an algorithm to calculate whether an object is in the parking space and, if so, how big it is and how it is positioned. “The asphalt constantly reflects microwaves to the sensor. As soon as a car moves into the space, the microwaves are reflected to the sensor differently,” Poprawa explains. The information exposed to individuals is far below statutory limits.

The sensor consists of an antenna, an analog electronic system, an analog-to-digital converter, and a signal processing component. It should be possible to integrate it into the urban infrastructure without too much effort. The reason for this is simple. Because the sensors are so small, they can be installed in streetlights, where they can be supplied with electricity. From above they can monitor an area measuring approximately 30 meters by nine meters, which corresponds to about five to seven cars parked in a row.

The software’s special feature is that it works with learning systems. It notes situations in which parking spaces are occupied in recurring identical cycles — for example, if they are very frequently occupied or rarely used at certain times of the day or on certain days of the week. It then uses this information to calculate forecasts for road users about the parking situation they will probably find on reaching a given destination.

Stress-Free Parking. Advanced Parking Management could also help to make city parking less stressful and optimally distribute parking spaces. This would involve automatic pricing models that are adjusted to the time of day, the day of the week, and the length of time a car was parked. For example, a city could charge lower fees on side streets with less traffic than on major streets with lots of traffic. Parking could thus be spread more evenly among various neighborhoods, to the benefit of the city, drivers, and residents.

The system has obvious advantages. Road users would spend less time and energy looking for a parking spot, and driving in major cities would become a more relaxed experience. Noise and emissions would decrease. That’s not all. Many different functions could be added to the system in the future. For example, Siemens experts can imagine equipping cars with RFID chips in order to increase transparency in reserved residential parking areas. Before starting out, drivers could use an app linked with the system to find out where they could park within their destination area and which spaces would be reserved for residents. One aspect of this idea has already been tested: Street-mounted RFID sensors that read vehicle chips and a sidewalk-mounted LED display indicates whether or not a driver is authorized to park in a particular space.

Such a system could help cities to efficiently locate illegally parked cars by means of software based on data from radar sensors. An additional feature could permit drivers to pay parking fees by means of an RFID code. In the future, this function could calculate parking fees automatically at the minute, without involving cash. There would be less bureaucracy and fewer parking meters — and cities would save money.

“The system can do a lot more than simply optimizing the parking situation,” says Poprawa. Sensors could conceivably have additional functions, such as measuring traffic flow, optimizing autonomous vehicle navigation, or informing drivers of electric cars regarding charging station services. “Of course we want to make sure that drivers who have no chance of finding an empty spot at their destination can use public transport,” Zwick adds. It would also be possible to transmit information about traffic density to control centers for a city’s street lighting system. The centers could then adjust lighting to fluctuating traffic needs. “Our parking space monitoring system could thus play an important role in the smart city of the future,” he concludes.

Ulrich Kreutzer

For more on intelligent parking systems, see Pof Digital: www.siemens.com/pof-parking-sensors
A diver is gliding above gigantic steel skeletons. Her swim fins are hardly moving, and air bubbles rise from her mouthpiece only at long intervals. Her gaze sweeps from gorgonian sea fans to the rows of tube sponges that started colonizing the artificial reef below her, a former drilling platform, 20 years ago. Today colorful sponges and corals are growing all over the reef, creating a paradise for fish in the Gulf of Mexico.

The diver finds what she’s been looking for. She moves her wrist slightly, shoots—and suddenly an impressive sea bass is wriggling on the tip of her harpoon. Ten minutes later, Vanessa emerges from the water and reaches for the ladder. Once on board, she first gives her husband Alfredo the harpoon, then the fish she has caught. She wrings the water from her long hair and glances at the message on her waterproof smartwatch: “Oil price forecast: Falling.” Vanessa gives her husband a quick peck on the cheek.

“Honey, you’ve caught a real beauty again,” says Alfredo admiringly. He hands his wife a towel. As she dries herself off, she says, “Could you put the fish on the grill? I have to go to the holoroom.” Her husband raises an eyebrow: “Not again? You’re more addicted than the kids.” Vanessa smiles gently. “Alfredo—then there’s a long pause. “You wanted to live on a boat. I have to work now and then, that’s all. Or should we move back to Houston?” Alfredo doesn’t answer, turns around, and silently lays the fish on the table next to the hot charcoal grill.

Vanessa shoos her children out of the holoroom and starts to focus on her work. Her smartwatch had already predicted a fall in the oil price for the coming weeks even before she made her dive, and this trend has intensified in the past half-hour. She now urgently has to gain an overview of the situation. “Hello, Vanessa. You look great as always. I’m sure you want to look at the price forecasts in more detail,” says Geoff, her virtual assistant, by way of greeting. Vanessa and Geoff are a well-oiled team. Geoff almost always knows what Vanessa wants to do next. While he prepares the presentation, she looks through an underwater window, and her gaze wanders across the artificial reef in the distance.

Only ten years ago, oil and natural gas were extracted here. Back then, environmental activists were demanding an end to outdated and expensive oil and gas extraction via drilling platforms. Since then, several thousand such platforms, together with their steel skeletons—like the ones in this area—have been lowered to the bottom in an environmentally friendly manner and transformed into artificial reefs. In the past 20 years, the technologies for subsea oil extraction by means of automated production systems on the ocean floor have made considerable progress, and costs have floated downward.

Extraction equipment is installed on ocean floors by robots, after which production plants operate autonomously for decades. Oil flows through induction-heated pipes to land, where it is refined almost completely automatically. Specialized ships manned by skeleton crews are needed only for the initial installation and for drilling bore holes; they drive the drilling cores thousands of meters down into the ocean floor.

Vanessa puts on her 3D goggles and snaps at Geoff: “Why is the price going down so fast?” Her virtual assistant replies, “We’re assuming that a lot of capacity is being added to the market. Some shale gas fields in Argentina have been developed faster than expected. And somebody’s ordering a lot of new
equipment on the automatic auction mar- kets. That means additional oil fields will be developed in the coming months. Besides ... there’s something else, you won’t like it.” Vanessa sighs.

Ever since oil production was largely au- tomated, her life has changed. There are hardly any more jobs now on offshore sta- tions. Thanks to fast data connections, au- thorized production engineers like Vanessa can monitor the status of oil fields from any- where in the world and intervene at high level decision-makers.

That’s why Vanessa and her family were able to move to a houseboat on the high seas — something Alfredo always wanted. “I’m the last offshore worker in the oil and gas indus- try,” Vanessa jokes sometimes. Nonetheless, the transformation has not always been easy. “The only jobs that are left for me are the really hard ones that require intense concen- tration and the development of creative so- lutions,” she says.

At the beginning of her career, she still had to decide whether an individual valve here or there should be opened or closed — and in some cases she had to do it herself by hand. Today all the components of an oil field automatically communicate with one an- other and decide for themselves what they have to do to optimize production. This pro- duction volume, in turn, is determined by al- gorithms that are based in part on complex

Warming up Ice Cold Gas

A Siemens IGT-750 gas turbine is being used in a novel way: to heat extremely cold natural gas from Russia as it arrives in the North Stream Pipeline at the German Baltic Coast. Once the gas achieves its ideal temperature it can be fed into the European natural gas net- work. As a byproduct, the turbine also provides around 50,000 households with electrical pow- er. This marks the first use of the IGT-750 gas turbine, which has an output of 37 megawatts. Siemens developed the turbine in Sweden, where it is also manufactured. Solutions, such as the turbine’s high compressor ratio, im- proved flow ratio, combustor arrangement, and blade coatings are the reasons for its excellent electrical efficiency of nearly 40 percent. While this percentage of the turbine’s power gener- ates electricity, the remaining 60 percent con- sists of waste heat at a temperature of 459 de- grees Celsius. Whereas combined cycle plants use this heat to run an additional steam turbine, the cogeneration plant in Lubmin, Germany uses it to heat the natural gas from the North Stream Pipeline. The gas turbine’s design not only improves its efficiency, but, thanks to the use of smart data, reduces maintenance-related downtimes.

China’s Coal

China is the world’s largest consumer of coal, but air quality is awfully bad in China. However, it could be improved with the help of coal gasifi- cation — a technology in which Siemens spe- cializes. In this process, powdered coal and wa- ter are gasified at high temperatures. The result is a synthesis gas of hydrogen and carbon monoxide. This gas can be reacted with water to create carbon dioxide and even more hydro- gen. A coal gasification plant produces extreme- ly pure hydrogen that can then be mixed with natural gas and turned into electricity. The CO2 that is generated in the process is already sepa- rated so that it can be stored underground in- stead of being emitted into the atmosphere. Siemens engineers in Beijing are also working on the CO2-free use of coal in combination with renewable sources of energy.

Floating Power Plants for Japan

Siemens and the Norwegian company Stavne Marine are working on a concept for floating power plants. Anchored off the coast of Japan, such facilities could withstand earthquakes and tsunamis of the magnitude of those that affected the eastern coast of the country in March 2011. That disaster caused a meltdown at the Fukushima nuclear power plant, causing Japan to shut off its nuclear reactors. Since then the country has been able to slowly its power needs only at substantially higher cost. Siemens has been able to quickly gasification plants. The gas can then be fed into the European natural gas network. The resulting hydrogen can be used in fuel cells to generate electricity or can be used to produce synthetic natural gas. Siemens has been working on the installation of the first pilot plant in Japan.

THE FUTURE OF OIL AND GAS

www.siemens.com/pof/japan

Best of Pictures of the Future, Spring 2015

Best of Pictures of the Future, Spring 2015
In the space of just a few months, between late 2014 and early 2015, oil prices fell by roughly fifty percent. This happened because more oil reached the market, and partly because demand growth had weakened. It was not the first time oil prices took a hit. They have always been volatile, but even more so during the past decade, explains Lisa Davis, the member of the Siemens Managing Board who is responsible for Siemens’ Oil & Gas businesses.

Oil’s low price is both a challenge and an opportunity for the industry. Well run oil and gas (O&G) companies that are strong today are likely to emerge even stronger after prices rebound. While the availability of oil fields and associated equipment is always paramount for them, during a slump they have every reason to also focus on cost effective production. Often this means bringing in new technologies and changing processes. Siemens is in a good position to help. The company recently acquired Rolls-Royce’s aeroderivative turbines unit. Such turbines are particularly suitable for the oil and gas production environment. And Siemens is planning to acquire Dresser-Rand, an important O&G industry supplier. “We have a lot to offer in three areas: electrification, automation and digitalization. These three areas have one thing in common, they are all about increasing efficiencies,” explains Davis.

Unconventional Oil Boom. Lowering production costs is not just an imminent need of the industry. It is also a long-term trend. Most of the “easy oil” has already been extracted – oil that can be produced cheaply because it is onshore, close to the surface, and conveniently spilling out of the ground under high pressure. Other sources, often considered to be “unconventional oil and gas,” require a lot more ingenuity and sophistication to tap. These include, for example, oil and gas deposits that are deep underground, offshore, or locked in shale or in oil sands. On the whole, it is becoming harder to produce hydrocarbons. But there is also good news: this needn’t make O&G more expensive. We just need to get better at extracting them. As in the past, technological innovations, as well as more cost-effective processes, will make up for these increased difficulties. What is considered unconventional oil and gas today is likely to become tomorrow’s conventional O&G. In this connection, the following trends are already taking shape:

- Existing fields will run longer and their yield will be increased by injecting water or CO₂, which boost the pressure of the reserve.
- Fracking is likely to spread beyond North America.
- Production of heavy oil, e.g. from oil sands, will become more environmentally friendly and less energy-intensive. (see page 26)

The global market for liquefied natural gas (LNG) is expected to grow robustly. More of the gas that is being flared, and thus wasted, today will be processed and add to market capacity tomorrow. (see page 23)

One day, we will even see automated oil fields at the bottom of the sea, working maintenance-free over decades, at depths of several thousand meters. (see page 20)

At the same time alternatives to O&G are becoming increasingly viable. Electric cars may become more commonplace. And renewable sources, such as wind power, are be-
Automation and digital technologies are expected to keep oil and gas competitive for decades. That will probably hold true until, one day in the future, it will be permanently more economical to leave the remaining oil in the earth’s crust rather than extracting it. This gradual transition will bring great business opportunities for those who have the courage to innovate and try out new ways to produce and use O&G. “When you look at the growing demand and at the sources of energy we have, it quickly becomes clear that oil and gas will remain crucial for the next few decades at least,” says Lisa Davis. “We will also need renewables. For the time being we need everything we have. And that includes oil and gas.” Andreas Kleinschmidt

What is the future of oil and gas over the next 20 years?
Abdul-Hamid: News of the end of oil has been exaggerated. We saw on average 91 million barrels of demand every single day in 2014. By 2040 we expect 111 million barrels of demand per day. We at OPEC believe there are sufficient resources to satisfy growing demand for oil. New capacities from unconventional sources are a case in point. Demand growth mainly comes from emerging economies and developing countries, particularly in Asia, and from OPEC member states. Their demand more than compensates for shrinking use in highly developed countries. Developed countries are reducing their oil consumption due to increasing fuel efficiency. Demand for oil will be in transportation and petrochemicals. Efficiency is increasing, electric cars and hybrid vehicles are on the roads, renewable energy has entered the stage. Will mankind lose its interest in oil long before it runs out?
Abdul-Hamid: It is worth taking a historical perspective. Often new sources of energy complement existing ones. Coal was dominant globally before oil entered the market. But we continue to live with demand for coal even as gas has become a major source of energy. Mankind will keep using a lot of fossil fuels, both near term and long term. Having said that, the share of renewable sources of energy such as solar and wind is still modest but is expected to grow in the future.

Today, the U.S. is an importer of oil. But because of huge supplies of unconventional oil from fracking it may soon become an exporter. What is the role of unconventional oil and gas going forward?
Abdul-Hamid: The effects of fracking in producing unconventional oil in North America have been seen over a relatively short time. However, on a global scale, fracking makes up only a small proportion of total production. Our forecast in the 2014 OPEC World Oil Outlook sees 3.8 million barrels of tight crude per day coming from fracking. Similarly, unconventional natural gas liquids contribute an additional two million barrels per day. These rates, when compared to the 91 million barrels per day of total world oil demand represent a small proportion. This contribution to
Some describe the oil industry as conservative. It appreciates proven equipment that has been tested for years and will run under virtually any condition. Is this really a great environment for innovation? Abdul-Hamid: Innovation is a necessity for our industry to continue to be reliable, safe and capable of meeting expectations. We value specifications, robustness and reliability from a safety perspective, because we have a responsibility to our people and the communities we operate in. Availability of equipment is crucial from an economic point of view, too. When a field does not produce because of a technical defect, oil companies lose a lot of money. But it is a wrong perception to say the oil and gas industry is not innovative. Over the course of the last few decades we have managed to produce oil under ever more challenging conditions. You can simultaneously sustain cultures that appear to be contradictory on first glance: the oil and gas industry is both conservative and innovative.

What’s the role of technology companies in this respect? Abdul-Hamid: They play a significant role. We think of Siemens and other developers as enablers that can take us to the next level technologically. One area where we need to get better is our own fuel consumption as an industry. You need energy to produce oil, for pumps, compressors and many other machines. Increasing their efficiency is good for both the economics of oil and gas and for the environment.

Is one way to achieve this the electrification of equipment? Abdul-Hamid: Right. Today, many machines are directly driven by rotating equipment, for example by a gas turbine. In the future, more machines will be driven by electrical motors. This saves energy and therefore money. But we need to show the actual return on investment to convince end users. Operators can feel comfortable with existing technologies and it may take a while to retrain and get them accustomed to a new version of a technology. Remember, oil companies have already invested in infrastructure they find reliable. So it takes effort to convince them to move to the next level. It’s a bit like driving a car, some people feel very comfortable driving with a gear shift and hesitate to switch to automatic.

Since you mentioned cars, what would it take for you to switch to one with an electric motor? Abdul-Hamid: It would have to be cheaper and reliable enough to get me from A to B. But it is a tough call here in Vienna, because there is an excellent public transport system. There are many alternatives to getting from A to B. You can walk, bike or use the tramway. And when you leave the city you want a car with a long range, which electric cars don’t offer, because energy storage is still very difficult and expensive. Also, building a charging infrastructure for electric cars is costly, while a network of gas stations is already in place. It will take some time until electric cars become acceptable for more people.

Your kids are in their teens right now. In 20 years they will be in their mid-thirties. Will they drive cars with combustion engines or electrical vehicles? Abdul-Hamid: It depends on where they are: in a city or in the countryside. At OPIC we continue to subscribe to oil being a wonderful source of energy that is very suitable for use in transport. And it will continue to be for the foreseeable future. We are seeing a lot of investment in combustion engines, making them more efficient and environmentally friendly. The combustion engine will be around for quite some time.

What is the most important thing your kids need to know about energy? Abdul-Hamid: They need to appreciate that they need energy for their prosperity. And it is not always easy to decide where it should come from. The conversations we will see over the next decades will revolve around air pollution, climate change and the efficient use of limited resources. Taking care of the environment will become more important, globally. And technology can help with it. At the end of the day, having resources also brings the responsibility to use them wisely.

Andreas Kleinschmidt

Going Offshore Online

Remote and technologically complex industrial facilities are characterized by high costs associated with plant design, maintenance, and workforce training. This is especially true for offshore oil and gas extraction. In view of this, Siemens has developed simulation software that generates precise, three-dimensional, virtual representations of facilities, including detailed information regarding associated components. The software is ideal for training technical personnel. What’s more, training can take place without setting foot in offshore facilities, resulting in huge potential savings.
The Future of Oil and Gas

The expression, “an ounce of prevention is worth a pound of cure,” applies well to industrial extraction and manufacturing facilities. Prevention is cheaper, after all, because the really expensive element of corrective work consists in the “job orders” performed by employees directly on a platform. The advantage of COMOS is demonstrated by an example. Whereas 3,670 corrective work orders had to be performed at a customer when COMOS was first introduced, this figure dropped to only 1,778 units three years later—an almost 30-percent reduction.

COMOS not only provides the digitized data required for planned and coordinated maintenance work, it is also linked to a 3D visualization tool that can do a lot more than conventional 3D CAD models. “It’s like a snow globe,” explains COMOS Marketing Manager Manuel Keldenich. “CAD lets me build the globe,” explains COMOS Marketing Manager Manuel Keldenich. “CAD lets me build the globe, but the software simulates all three dimensions, it is also ideal for training purposes. Total E&P, for example, used COMOS Walkinside’s Immersive Training Simulator to train its workforce for duty at remote offshore installations. One such installation is the Pazflor FPSO off the coast of Angola, for which employees were trained while the production unit ship was still under construction in a shipyard in Korea. The training sessions in the virtual model reduced the time needed to prepare workers, thus helping put Pazflor into operation more than two months earlier than planned.

Predicting Corrosion? A huge benefit of asset information management with COMOS is that it enables all users to access precisely the same up-to-date information at all times—as well as a system’s entire history. Even more time and money can be saved if the software solution is used during the engineering process. For example, it enables an occupational safety officer who doesn’t understand technical drawings to say in advance—whether a ladder must be installed at a given location to ensure rapid evacuation during an emergency. Moreover, it can tangibly show engineers that a valve would be much easier to maintain if it were turned by 90 degrees, for example. Such a complex technical environment contains pitfalls at literally every step.

Even the developers of COMOS are continuously discovering new things that can be done using the software. “The more the software achieves, the more people demand of it,” says Larsen. The next task that Larsen’s team will be working on involves the stiff North Sea breeze. According to Larsen, a customer’s oil platform was so cleverly built that it aligned with prevailing winds to cool the facility. Unfortunately, however, wind contains a lot of salt on the high seas, causing it to form a fine film on the technicians’ faces and clothes as well as on steel components such as stairs and railings. The salt slowly but steadily corrodes metallic components—a factor that the software does not yet take into account. In the future, COMOS will also monitor this kind of condition so that the data can be accessed with just two clicks of the mouse to ensure optimal maintenance.

Sandra Zistl

Experience a virtual model of an offshore oil platform:
www.siemens.com/pof/comos

COMOS Walkinside helps users plan and simulate complex service projects.

COMOS bundles current and historical facility data. The software translates engineering data into its virtual world counterpart. Once within a realistic 3D environment, the user can move about freely as an avatar. Real-time information regarding all of an installation’s components is available not only to engineering experts, but to everyone involved in a project.

The Huge Cost of Downtime. The currency of commercial projects is time. Especially in the oil and gas business, time is money. Projects become especially expensive when the associated work not only takes a long time, but also requires a partial or total shut-down. Unfortunately, that’s what often happens whenever repairs have to be carried out in automated processes that are precisely coordinated with one another. An average production platform extracts about 100,000 barrels of oil and up to 20 million cubic meters of natural gas every day—the latter the equivalent to the annual consumption of about 10,000 German households.

“A single day of downtime would cost the plant operator several million euros,” says Kristian Larsen, a project engineer at Siemens Industry Software. “It is therefore only logical that platform operators want to reduce the number of lost days. Not only every day, but that platform operators want to reduce the number of lost days. Not only every day, but...
Jan Erik Lystad says that pressure doesn’t bother him much. A glance at the 60-year-old Norwegian engineer, who joined Siemens 14 years ago, makes you believe him. With his jeans, blue checked flannel shirt, and hands-in-pockets stance, Lystad looks as though nothing could faze him. He has spent all his life in Trondheim, where he went to college and raised his children. He perfectly reflects the qualities of this picturesque city of 180,000 inhabitants, where meter maids ride bicycles and continuity is important.

However, Trondheim’s sedate facade hides a veritable volcano of bright ideas and innovations, powered by scientists such as Lystad, dozens of research institutes, and thousands of students at the city’s technical university. The epicenter of this volcano is often the Siemens research center in Bratsbergveien, just a few kilometers from downtown Trondheim. In 2012, researchers here developed the world’s first electric ferry. And now another eruption is imminent, as Lystad’s lab is literally operating under high pressure.

“We have a kind of torture chamber lab for technical components,” he says. “We put parts under enormous pressure. The technology has to withstand up to 460 bar — that’s how high the pressure is at a depth of 4,600 meters.” However, Lystad’s unique torture chamber lab is not so much a place of agony as of pioneering work. In the lab, ten engineers test components for a power network that will supply energy to future deep sea facilities. Beginning in 2020, the Norwegian energy company Statoil plans to use such self-sufficient oil and gas extraction factories on the ocean floor.

Siemens technology will supply the pumps and compressors with electricity. By then, individual network components will have to demonstrate that they can withstand the extreme conditions found at depths of at least 3,000 meters under the sea. This is a huge challenge, as researchers have had no experience with network components at such depths, where they will have to withstand 300 kilograms of pressure per square centimeter in perpetual darkness. “Transformers, frequency converters, and switch-gears have to operate flawlessly in such environments. What’s more, they have to do so for 30 years, because it would be difficult to service them down there,” says Lystad. “Only if electricity flows with absolute reliability will it be possible to relocate today’s production platforms to the ocean floor.”

Self-Sufficient Underwater Factories. Such self-sufficient deep-sea factories with their own power supply systems are not yet available. Although there are already a few facilities that operate on the ocean floor, they are connected to floating platforms and have to be individually supplied with electricity through dozens of cables. And the raw materials that the facilities pump out of the ground are still processed on the surface as well. Subsea technologies currently work only in shallow waters. Moreover, they are expensive and complex. As a result, the majority of the oil and natural gas produced offshore today is still pumped by traditional production platforms. Only a small percentage is extracted directly on the ocean floor.

Lystad believes that in the future this ratio will be reversed. “The trend is toward previously unexploited deposits in the deep sea and the Arctic, which are difficult to reach with conventional technology,” he says. Self-sufficient underwater factories would thus make sense in such areas. “Although conditions on the ocean floor are extreme compared to those on the surface, they are also stable. Temperatures stay at around 4°C and there are no storms or icebergs,” Lystad explains. “This makes deep-sea facilities much less prone to faults and more cost-efficient than conventional systems.” Their only connections to the surface would be a power cable and a pipeline, which could reach land whenever the facilities are not too far offshore. A deep-sea-compatible power supply could also boost a facility’s production capacity — for example, by ensuring that many more pumps could be in constant operation. “The new technology would enable us to exploit around 60 percent of a reservoir. We can’t achieve more than 40 percent with current subsea technology,” says Lystad.
The Future of Oil and Gas

Liquefied Natural Gas

In many countries, new plants are being built for the production of liquefied natural gas (LNG). Siemens is involved in most of these projects.

Few segments in the energy market are growing as rapidly as the production of liquefied natural gas. About a dozen new plants worth many billions of euros are being planned around the world. The International Energy Agency (IEA) predicts an annual growth rate for the LNG market of up to 40 percent. Siemens has already delivered compression systems, drive systems, and electrification components to about 40 plants worldwide and will be involved in practically all the new projects.

Components are not considered to be deep-sea compatible until they have survived months of torture.

The test they will be submerged into the sea’s eternal darkness for the first time. Lystad scratches his beard in satisfaction. “It’s fascinating to work in regions most people regard as totally inaccessible,” he says. He is delighted by his young colleagues’ progress. “We’re a big happy family and we work closely with the Norwegian University of Science and Technology in Trondheim. I studied there and so did all my engineers.”

Lystad。“Basically, we take the components apart and look for tiny cracks or deformations.” The technology isn’t considered deep-sea compatible until the inspectors cannot discover any faults with their trained eyes. However, Lystad points out that parts are not always up to scratch. “It’s a major challenge to find components that can withstand such extreme conditions, because no manufacturer offers products that are especially designed for such depths. We are continuously entering uncharted territory.”

Eternal Darkness. Once all the parts have passed their tests, they are combined into a network component and firmly screwed onto a platform that is covered with zinc plates to protect it from salt water corrosion. Finally, engineers cover the system with a housing.

In the future, control centers will monitor deep-sea installations. Components for such facilities are being tested in Trondheim’s harbor today.

In the depths of the ocean in this video about subsea power grids: www.siemens.com/pof/subsea

Visit the depths of the ocean in this video about subsea power grids: www.siemens.com/pof/subsea

Best of Pictures of the Future | Spring 2015

Siemens is involved in most of these projects. A mid-sized facility with an annual output of five million metric tons of LNG can come with a price tag in the five billion euro range. In spite of this, LNG is experiencing a sustained boom that began around 2005. Since that time, LNG has grown from a niche supply source into one of the most important fossil fuels, according to a 2014 study conducted by the Oxford Institute of Energy. If the natural gas reserves being targeted for extraction are located more than about 2,000 kilometers away from consumers, it is worth investing in the technically complex process of natural gas liquefaction. Ships and trucks then transport the liquefied gas to centers of demand. Once there, it is converted back to its gaseous state and fed into the national supply grid.

A commercially mature method of liquefying natural gas was developed as early as the 1960s. The first LNG export facility was built in Algeria, and its liquefied gas was...
Best of the Future of Oil and Gas

The Future of Oil and Gas

Shipped to France and Great Britain. The essentials of the technology have not changed since then.

**Powering LNG Plants.** An LNG export facility is a monument of top-notch technical performance, a system “of practically unrivalled complexity,” says Theodor Loscha, an expert in LNG at Siemens Power and Gas Compressors. Huge compressors, for example — which can easily weigh over 150 metric tons — power the cooling cycles.

In the first 30 years of LNG history, the energy for these compressors was supplied primarily by gas turbines. Their advantage is that they can be powered directly with extracted natural gas, and the system can be run without an external electricity supply. But large gas turbines are also inflexible and can’t be adapted to a variety of production levels, which isn’t very efficient, says Loscha.

The solution lies in speed-controlled turbines. Indeed, thanks to its acquisition of Rolls-Royce Energy’s gas turbine and compressor business, Siemens now offers aeroderivative turbines of this kind in its product range.

Another way to power compressors is by using electric motors. Siemens can therefore build an entire power plant immediately alongside an LNG plant. This provides a constant supply of electricity and thereby increases the efficiency and availability of the plant.

**Technologies that Maximize Efficiency.** Electric LNG plants require a broad range of power grid technologies, including switches, converters, and associated automation programs. An example of a model project of this sort is the Snøhvit installation in Norway, which entered service in 2008. Here, Siemens used large, speed-controlled motors — which was a first for an installation of this size. Since then, Siemens has built approximately 40 much smaller facilities, primarily in China. These have an output of about 0.4 million metric tons per year and are powered by electric motors.

“The way a new installation is planned depends first of all on the size of the natural gas reservoir to be exploited and the type of gas involved,” says Loscha. At present, demand for LNG is rising steadily. New import terminals are being considered. Operators can do without expensive undersea pipelines. The largest floating offshore installation is Prelude, which is currently being built by Royal Dutch Shell. It will exploit a gas reservoir of the same name off the coast of Australia starting in 2015. Siemens too is represented in this market with combined flash/boil-off gas compressors. Two more FLNG installations are being built for use in the Timor Sea in the Indian Ocean. Katrin Nikolaus

Boil-off systems are essential to LNG facility efficiency, and Siemens has set the standard.
Fresh Recipes for Extracting Oil

Lower CO₂ emissions, less water consumption, and high efficiency. Electromagnetic induction techniques could help make it possible to get more heavy oil out of deposits in the future — and in an environmentally friendly manner as well.

A lush meadow with stalks and blossoms gently swaying in the breeze. The edge of a forest can be seen on the horizon. There’s little to indicate that a new method for oil extraction is being studied here just outside the Bavarian town of Deggendorf about 150 kilometers northeast of Munich — except a white trailer adorned with the turquoise lettering of the Siemens logo in the middle of the meadow. A path made of gray wooden boards leads to the trailer because the ground here is saturated with water — an important factor in view of the technology being tested here.

Electromagnetic induction technology could greatly facilitate the extraction of heavy oil in the future. This would be a major innovation, since heavy oil is difficult to get to, and most of the easier-to-access petroleum sources have already been discovered and are being exploited. Difficult to reach deposits are therefore becoming more attractive to the oil and gas industry — including those that contain heavy oils, which are extremely viscous and therefore hard to remove from the pores in rock formations.

Heat from Eddy Currents. One way to effectively extract viscous oil is to pump hot steam into the ground at high pressure. With this technique, the heat from the steam liquefies the viscous oil trapped in rock pores, which allows it to flow to a production well and the surface more easily.

Another method, one that requires no steam whatsoever, involves electromagnetic heating (EM Heating). A technology Siemens is working on with oil and natural gas producers to help get to oil that's difficult to reach.

Experts expect that more than three trillion barrels of heavy oil can be exploited worldwide. The future of Oil and Gas — and in an environmentally friendly manner as well.

Hybrid Techniques. Depending on the properties of the heavy-oil reservoir in question, induction can be a sufficient procedure in the first phase of oil extraction. However, it will often be combined with another method in the future in order to exploit its full potential.

In such a hybrid technique, inductive electromagnetic heating will supplement the steam flooding process. Here’s how such a method would work: Steam is injected horizontally into a reservoir. The surrounding underground area gradually heats up in a fan-like pattern. However, the spaces between two production bores remain outside the steam chambers, and the ultimate recovery factor thus totals 40–50 percent.

The inductor cables that directly heat up the oil site are installed in the areas outside the steam chambers. As time goes on, the steam chamber interacts with the oil heated by induction, thus extracting oil from the spaces in between as well.

Increasing Yields by up to 20 Percent. Simulations conducted by Siemens and Wintershall show that this hybrid technique allows reservoirs to be exploited up to two years more quickly and — more importantly — considerably more efficiently during this period. The combination of the two methods also significantly reduces the amount of steam (and thus water) needed for each extracted barrel of oil.

Naturally, the hybrid technique could be applied in a more environmentally friendly way if the energy used to heat the ground were generated from renewable sources.

Sandra Zistl
**Even as Renewables Boom, Oil and Gas**

Energy systems are undergoing changes in many countries. Decentralized energy generation, intelligent power grids, unconventional sources and, of course, renewable energies are at the top of the agenda. But the energy boom is far from over. The world’s leading fossil fuel, oil, remains the main source of energy for its efficiency as well as its share of the energy mix hadn’t been that low since 1965.

At the same time, there was a sharp drop in prices: while a barrel of oil cost over US$110 in June 2014, it was just over US$50 in spring 2015. The reasons for this are complex. Among other things, a flagging global economy is leading to reduced demand for oil. At the same time, the United States, historically a major oil importer, has drastically reduced imports because of its own booming oil production; and Saudi Arabia, as the world’s largest exporter, is not prepared to produce less oil in order to stabilize prices.

**Natural Gas: A Worldwide Success Story**

In its “World Energy Outlook” report of 2014, the International Energy Agency (IEA) has forecast 37% growth in global energy demand by 2040. However, annual growth rates, which have been over 2% until now, will be only half as large after 2025. Fossil resources accounted for almost 82 percent of global energy consumption in 2012, and their share is expected to be about 75 percent in 2040. Global demand for natural gas is expected to grow in all regions from 2010 to 2035. The primary drivers will be China, at 6.6 percent annual growth, and India, at 4.2 percent.
The Nigerian Dream

Nigeria needs oil in order to end its dependence on oil. The country plans to use the income it generates from the energy sector to build up its infrastructure and establish new industries. In the process, Nigerian engineers are facing increasingly complex challenges. Siemens employee Waheed Raji, for example, is responsible for servicing three gas turbines offshore.

It’s 9 a.m. on a Monday morning. Waheed Raji’s eyes are closed and his head is slowly sinking sideways. The monotone drone of the rotors and the engines always puts him to sleep. He has taken this trip so many times that the view from the helicopter’s tiny window no longer overwhelms him. There’s nothing but rainforest down there, as far as the eye can see. Sunlight is reflected from the surface of the Bonny River, which branches many times before flowing into the Gulf of Guinea in southern Nigeria. Raji doesn’t open his eyes until the helicopter begins its approach to his workplace, the FSO Unity, which stands for “floating storage unit off Nigeria’s coast.”

Above and middle: Waheed Raji inspecting FSO systems. Safety is a top priority. A fireman stands watch (below) during helicopter arrivals and departures (left page bottom).

The helicopter has now almost landed on the roof of Unity’s residential section, which houses 140 beds and the vessel’s control room. Raji points to three smokestacks that rise above a jumble of pipes. The smokestacks are part of the gas-fired power plant whose Siemens turbines Raji is responsible for servicing. If the turbines were to fail, oilfields linked to Unity would have to shut down production sooner or later. A lot therefore depends on his work. The helicopter lands with a slight jolt. Raji’s world has begun.

“Each turbine has an output of almost five megawatts,” Raji explains as he puts on his blue work overalls and exchanges his elegant, black leather shoes for safety boots in the locker room. “A single turbine is enough to operate the entire facility, the oil pumps, and even a desalination unit. We have three identical turbines on board in order to make sure at least one is running at all times.”

Siemens is responsible for servicing and maintenance of the gas turbines. In early 2014 the company was still flying in engineers from the UK to do the job in shifts of 28 days each. Raji is the first Nigerian to take on the assignment. Clearly, if the installation were to break down, things could get very expensive for its operator and daily losses could go into the millions. Raji can partly thank Modele Idiahi for his offshore job. Idiahi, who is based in Lagos, is responsible for developing Siemens’ Nigerian energy business. “We need to identify and support talented individuals in Nigeria,” says Idiahi. She supported the idea of investing in Raji’s training from the very start. Raji was trained by experts for the gas turbines used on Unity, and his training took him to Sweden and the UK, where the turbines were built.

When there’s a problem whose cause Raji cannot immediately find on his own, he knows whom to call — and because of his previous visits, he usually knows the person at the other end of the line personally. For Idiahi, all of this is not so much about Nigerian patriotism as it is about business. “We save money on the expensive flights for our British colleagues, and we also bring knowledge into the country — knowledge that Raji can pass on to his colleagues,” she explains. “In other words, we’re not just training one employee, we’re indirectly training dozens.” Idiahi herself grew up in England and also studied there, but instead of taking a job in London she decided to go to Africa because she wanted to embark on a career in a growth market. “I couldn’t imagine a better place to be at the moment,” she says. “The Nigerian economy is growing at a rate of around six percent per year. That can easily go on for another ten or 15 years — eventually making Nigeria one of the world’s 20 most important economies.”

A lot will be needed in order to get there — for example, roads, railroads, construction materials, food, and electronic systems.

Above all, the country will need energy. A total of 600 million people in Africa — or about 70 percent of the continent’s population — have no electricity. Nigeria alone has around 170 million people, and its population is growing at a tremendous rate. According to UN estimates, Nigeria’s population will increase to 440 million by 2050. Although Nigeria is the world’s eighth-largest oil producer, its power generation capacity is only around 4.5 gigawatts. By comparison, Germany currently has power plants with an installed capacity of 194 gigawatts. It’s therefore not surprising that Nigeria’s people experience frequent power outages.

In order to generate the same capacity per capita as South Africa, for example, Nigeria would have to increase its power plant capacity forty-fold, and even if it did, there would still be power outages. A single new power plant, such as Genegu 2, which is located some 200 kilometers south of the Nigerian capital, Abuja, is just a drop in the bucket. The facility, which has been operating since 2012 with turbines and generators from Siemens, has an installed capacity of 434 MW. Nigeria would need nearly 400 such plants to close its electricity-supply gap. And it’s not just power plants that are needed — there is also a shortage of refineries. Oil and gas account
Modele Idiahi moved from London to Lagos. Electricity is bringing hope to Nigerians. FSO Unity holds almost 2.2 M. barrels of oil. In Lagos, cell phones are everywhere.

Raji and Idiahi, but also for millions of their fellow citizens. A growing middle class has emerged, and its members are now able to afford many things for the first time. Raji, for example, benefits from the substantial bonuses he receives for offshore work. Re-example, benefits from the substantial

Diesel generators pick up the slack during blackouts, and 60 percent of all Nigerians ever, crude oil is often exported, processed abroad into gasoline, and then re-imported. "By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"I spend the whole day on top of a giant container filled with flammable material," says Raji. "But that's not all, by any means. Many years ago, I worked on an offshore rig that was targeted by pirates."

That explains the barred wire on FSO Unity's railings, which is meant to slow down attacking pirates in order to give the team time to barricade themselves in a bulletproof room. Until a few years ago, pirates were mostly a serious problem in the waters around Somalia in East Africa. Today the Gulf of Guinea is considered the most risky stretch of water in the world. "I spend the whole day on top of a giant container filled with flammable material," says Raji. "But that's not all, by any means. Many years ago, I worked on an offshore rig that was targeted by pirates.

That explains the barred wire on FSO Unity's railings, which is meant to slow down attacking pirates in order to give the team time to barricade themselves in a bulletproof room. Until a few years ago, pirates were mostly a serious problem in the waters around Somalia in East Africa. Today the Gulf of GUinea is considered the most risky stretch of water in the world. According to the International Maritime Bureau, almost 20 percent of all pirate attacks occur here.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.

Raji walks down steel stairs, wanders through a maze of ladders and pipes, and makes his way to the three turbine housings. He's wearing earplugs to keep out the deafening noise. He opens the door to the middle housing, inside it's dark, hot, and stuffy. The turbine in this housing was recently shut down for maintenance. One of the other two turbines is now supplying electricity to the FSO. Raji has to turn around and maneuver in a very tight space in order to carry out his well-practiced maintenance operations. It made sense to award Siemens the turbine servicing and maintenance contract, because manufacturers are generally the ones who best know their own machines.

Siemens is also using in Unity's fire protection systems and in the team's cabins, where thermostats from Siemens allow crew members to adjust the air conditioning system to make things more comfortable. "The gas flames on the oil platforms glow in the distance like magical torches that light up the sea."

People they don't know. Those who would like to enjoy a beer after work have to go without, since no alcohol is allowed on board FSO Unity. Jobs on the high seas are also among the most dangerous in the world. "I spend the whole day on top of a giant container filled with flammable material," says Raji. "But that's not all, by any means. Many years ago, I worked on an offshore rig that was targeted by pirates."

That explains the barred wire on FSO Unity's railings, which is meant to slow down attacking pirates in order to give the team time to barricade themselves in a bulletproof room. Until a few years ago, pirates were mostly a serious problem in the waters around Somalia in East Africa. Today the Gulf of Guinea is considered the most risky stretch of water in the world. According to the International Maritime Bureau, almost 20 percent of all pirate attacks occur here.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.

"By comparison, the statistically biggest risks on board seem rather mundane — things like tripping, slipping, and inattentiveness," Raji explains as he puts on his safety helmet and goggles. He opens the door to the deck and is immediately hit by a salty breeze. He's now in the work area, and he needs written approval in the form of a "work permit" to be there. These permits determine the daily work that is done on board. The rule is "No permit, no job."

Nigeria is dreaming of greater opportunity, safer streets and affordable education.
**Smart Levees Could Soon Be Saving Lives**

Learning systems that use intelligent data evaluation processes can monitor critical infrastructures in real time. Lives could be saved by a new early warning system that knows when levees are in trouble.

The levee starts to move. Pieces of turf flake off from its outer wall. The underlying clay then starts to rise. For a few seconds it looks as though the rampart is being inflated from the inside and expanding like a balloon. The pressure then becomes so intense that the clay breaks, creating a deep crack through which a flood of brown water gushes out into the meadow in front of the levee. A container on top of the levee tilts into the crack after the ground breaks away underneath. It is a scene of destruction.

Bursting a Levee on a Tablet Computer. A satisfied smile spreads across Bernhard Lang’s face. The levee-breaking experiment has demonstrated that his early warning system for protecting against floods is effective. Lang, an engineer at Siemens, began developing the system four years earlier in cooperation with researchers from Russia. Lang’s idea was to “develop something to protect against floods.” The resulting levee monitoring system is now ready for the market.

In the experiment, this sophisticated system calculated in advance exactly where the rampart would break, down to the last meter, and even showed how it would happen. Several days before the “break” occurred, a bright red area had appeared on a virtual cross-section of the levee that Lang called up on his tablet computer. Red means that the material they were made of, “I sometimes wonder why we Dutch people used to build all of our important structures below sea level,” jokes Peter Jansen, one of the organization’s standard tasks, it has never been as precise as it is today.

According to reinsurer Munich Re, some 37 percent of overall losses worldwide from natural disasters were flood-related in 2013, much higher than the 22 percent average for the period since 1980. The Netherlands in particular has often been hit by floods in the past. Over a fourth of the country lies below sea level, and 60 percent of it could potentially be affected by floods. “Up to now, levees received maintenance work every five to 30 years, depending on the material they were made of,” explains Jansen. Plans reveal how each dike is structured and which parts of it consist of sand, clay, peat or soil. Inspectors used to have to measure the levees at regular intervals to check their stability. “Every few years, a couple of experts used to drive out to look at the levees and stick their measuring instruments into the ground,” Jansen relates. The operators have to report the results of these inspections to provincial authorities. “We are responsible for keeping the levees stable,” Jansen says.

These days Jansen receives this information every hour on his cell phone. If the data gives cause for concern, Jansen can increase the frequency of messages up to once a minute. Does this mean that the inspection intervals for all the levees have been reduced from 30 years to 60 seconds? Not quite. That’s because the early warning and monitoring system developed by Lang and his colleagues at Siemens Corporate Technology has so far been installed only in a five-kilometer-long dike section in Amsterdam. Jansen can also ask the system to display curves that provide real-time information about specific points in particular areas of the levee or to automatically combine chronological data into a single graph. “All the data is there in the system, and it can be combined in any way we want,” explains Lang, the system’s inventor.

The data is collected by sensors that are inserted into the dike about every 100 meters. The sensors are located above and below the water surface, where they measure the temperature, pressure, and humidity within the levee as well as the depth and temperature of the water in the canal. The

Around 60 percent of the Netherlands could be affected by floods.

Best of Pictures of the Future | Spring 2015
Best of Gas Sensors | Respiratory Disease Detection

Digitalization & Software

n't necessarily mean that there is any danger. "It expands and contracts. The trained knowledge such as the depth of the first compares the real-time data with previous data. But before the system sounds an alarm, it must determine its "slope stability factor." Various factors are involved. But thanks to the use of the latest sensor data, a learning system’s continuous collection long-term data, and mathematical models, these factors are combined into a fascinating, unified whole.

Forecasts with Neural Networks. This is made possible by neural networks that distinguish between typical deviations and unusual anomalies. The associated software was developed by Siemens’ former "Neural Computation" department in the late 1990s and has been steadily enhanced since then. Today this software can extract and extrapolate the findings gathered at key points along the levee. The system can thus use its knowledge to draw conclusions about levee sections in which there are no sensors.

These findings are processed into color-coded graphic depictions that enable customers to see which levee sections could be endangered by a flood. The Siemens solution can also display scenarios that show what would happen at a particular point if the water level rises or the pressure increases, for example. It can also reveal how much worse the situation could get if the levee supports a road used by heavy-duty trucks.

"We’ve always had to deal with such issues," says Jansen. "But the information we previously had access to was theoretical and imprecise. Now it’s concrete and precise. He adds that the uncertainty about exactly what is happening inside the levees caused problems in implementing large-scale safety measures that in some cases were excessive. "It was expensive — the construction of a one-kilometer section of a new levee costs at least a million euros. But these levees were not even safe, because people had too little data," he says.

Jansen estimates that Watermeter will reduce maintenance costs by up to 20 percent per year in the areas where the Siemens technology is used. Costs will decline even though the operator will be receiving more data and better information. Jansen would like to install sensors into more levee sections. "Of course we can’t install them everywhere," he says; "it would be too expensive. But we could select certain model areas and extract information from them. Reliable, smart data is the tool we need to protect lives."

Sandra Zistl

Detecting Cancer through Breath Analysis

Detecting diseases by studying a person’s breath is not an easy assignment. However, scientists in the New Technology Field for Chemical and Optical Systems at Siemens Corporate Technology have become specialists in professionally capturing people’s breath and analyzing the molecules it contains. Their goal is to detect diseases such as lung cancer merely on the basis of the breath’s composition, and to do so when the illness is still at an early stage and therefore easier to treat.

Specialists from Siemens want to develop a sensor that can independently detect diseases such as lung cancer merely on the basis of the breath’s composition. Now that the groundwork has been laid, Fleischer believes that it is only a matter of time before researchers develop such a sensor. In other words, business as usual. "We gained extensive experience during our work on the asthma sensor, enabling us to develop a prototype. We can now build on these results," says Fleischer.

The asthma detection device works by measuring the concentration of nitrogen monoxide (NO) in a patient’s exhaled breath. If the result exceeds a given value, it means the patient has not been sufficiently treated with medication and is therefore likely to suffer an asthma attack. The sensor is equipped with a microchip, which is coated with a special substance to which the molecules to be measured in the breath sample selectively adhere.

A Breath Test with Your Next Checkup? Despite all of the technological advances and initial successes, the use of sensors to detect diseases is still in its infancy. However, researchers, medical professionals, and health-care managers have high hopes for these projects. If such sensors could one day reliably detect a wide range of diseases, they would be mass produced and used without greatly inconveniencing patients. Patients would merely have to give a breath sample, which could be taken during a routine checkup at, for example, a general practitioner’s office. If the sensor detected any anomalies, a more thorough diagnosis would then be made with the help of a computer tomography graph, for example.

A glance into Fleischer’s lab indicates that this vision may become a reality in the not-too-distant future. Katrin Nikolouros

For more information, contact:

Prof. Maximilian Fleischer, who is a driving force behind sensor research at Siemens Corporate Technology (CT). It is now clear that a whole range of molecules need to be detected for such a diagnosis. The researchers designed and developed a special device that was then tested at Erlangen University Hospital, where patients suffering from various stages of lung cancer are treated. The benefits would be especially big if this disease could be diagnosed as early as possible, as treatment is then much more effective than when the disease has progressed to an advanced stage.

Analyzing Hundreds of Molecules. Hospital staff used the new device to take breath samples from around 50 cancer patients. The samples were collected in special tubes, which were then sent to Munich, where Siemens researchers broke the breath down to the molecular level and analyzed it. Using a program that was specifically developed for this purpose, the researchers discovered correlations between the disease and a number of different molecules. The program was needed because it would have taken too long to manually analyze each sample for the presence of hundreds of molecules and document the relevant hits. In their efforts to analyze breath samples, the sensor researchers received help from Corporate Technology’s Analytics team. This research group, which is located on the same Munich campus as the sensor specialists, identified the various substances and contaminants in the samples. "All of this foundational work has rounded out our knowledge of molecules in the breath of lung cancer patients and what significance these molecules have," says Fleischer. CT is forming additional research partnerships, because the results still have to be validated in a larger study involving far more samples. The researchers want to develop a sensor that can diagnose whether a patient suffers from lung cancer purely on the basis of the breath’s composition. Now that the groundwork has been laid, Fleischer believes that it is only a matter of time before researchers develop such a sensor. In other words, business as usual. "We gained extensive experience during our work on the asthma sensor, enabling us to develop a prototype. We can now build on these results," says Fleischer.

The asthma detection device works by measuring the concentration of nitrogen monoxide (NO) in a patient’s exhaled breath.
at the beginning of the century, Germans haven’t wanted to have any more nuclear power plants, but they haven’t wanted wind turbines in their backyards either.

"Why are you shaking your head?" Max asks me reproachfully, breaking in on my train of thought. "Sorry, I was just thinking," I replied. "You know, as I stand here and watch you enjoying the plants and animals so much, I’m just as happy as you are. But I also become a bit thoughtful." "Why?" Max asks as he tries to sneak close enough to a swallowtail butterfly to take a macro photo with his sunglasses. When I was his age, this butterfly species couldn’t be found at this altitude of 1,800 meters.

What if We Hadn’t...

It takes me a while to find the right answer. "Well," I say, "because for a long time it looked as though you wouldn’t be able to experience this landscape the way you’re doing now." Max looks at me and wrinkles his brow. I always think it’s funny to see him put on his critical grown-up face. "You sometimes talk so complicated," he says, with an irritated undertone. How can I explain to him all the things that actually happened, or could have happened?

I remember the years when renewable energy sources began to become widespread. We knew in theory that we could not burn oil and coal forever and pump the atmosphere full of CO₂. However, not until the melting of the permafrost started to release hazardous methane, and storms, floods, and periods of drought became increasingly frequent did people begin to take action. If we had continued our behavior, the average temperature would have increased by 4 degrees Celsius. As a result, we tried and succeeded in limiting the increase to 2 degrees Celsius.

Everything Was Different.

It was a very grim era, and it was a very exciting time to be politically active. My predecessors and my colleagues in the state cabinet had made quite a few mistakes. When the first group of nuclear power plants was closed down in Germany, one of the issues up for debate was whether to set up large numbers of wind turbines in southern Germany. There was a big public debate about whether the landscape should be “cut up like a field of asparagus.” Back then wind turbines were much bigger than they are today; they didn’t look like the delicate structures we can see down there on the plains below. They were also much noisier and less efficient. Only when wind energy became cheaper than power from most fossil fuels did they finally become widespread.

A Landscape We Can Live With

Scenario 2060: A former state premier is hiking with her grandson through the Alpine foothills. They are gazing down at a landscape that looks very different from the way it did decades ago — thanks to a long-term emphasis on optimized use of renewable energy.
At that time I was the state minister in charge of the expansion of renewable sources of energy and the super grid. This ministry has been an independent unit only since I held that position. I didn’t want the entire Alpine foothill region to lose its recre-ational value either, and above all, I thought it would be a terrible idea to fill the mountain ridges and summits of the Alps with wind turbines. In any case, there was a heated debate about this issue, because the environmentalists and the Alpine Society naturally organized campaigns against these measures. So we had to find alternatives.

**Wind from the North.** “You know,” I say to my grandson, “when I was your age, these mountains looked exactly the way they do today. After I grew up, there were plans to set up wind turbines all over them and dig artificial lakes to serve as pumped-storage power plants. That didn’t happen, because smart people invented all of the great things you can see when you look down into the valley. Haven’t you had discussions in school about where our electricity comes from?” “Oh, that,” says Max, rolling his eyes. “I’ve just learned all that — that our power at school and for cars comes mainly from solar panels, wind turbines, and energy storage facilities, and the ultramodern gas power plants associated research project known as IREN2 is focused on building a smart grid in the municipal utility company and a facility operated by MTU onsite energy (MTU), which manufactures cogeneration plants.

**Local Energy Independence**

Siemens is studying new concepts for optimizing the cost-effectiveness and technical performance of energy systems based on distributed and fluctuating electricity production. An associated research project known as BENZ is being replaced by BENZ2. The initial project focused on building a smart grid in the municipality of Wildpoldsried in the Allgäu region of Germany. The project’s partners are now using the grid to examine ways to stabilize the electricity supply using intelligent sub-units that operate with a decentralized electricity generation system. They are also looking at ways to combine several small power generation units in a man-ner that would enable them to contribute to system stability in much the same way that conventional power plants do. Wildpoldsried sometimes produces more energy than it needs because many of its residents operate solar power units, windmills, and biogas systems, or cogeneration systems. As part of the BENZ2 project, additional diesel generators are being installed and these are playing a role similar to that of gas-fired power plants in large grids — i.e. making electricity available when it’s needed. Parts of the Wildpoldsried grid are now being combined in an independent grid equipped with its own energy management system.

**Knowledge Is Power**

A new mobile smartphone app from Siemens known as Energy Engage enables electricity customers in Colorado to manage their power demand — and save money. The app displays current energy use, the current cost of energy, the user’s projected bill for the current month, and the resulting savings (or extra costs) as compared to the previous month. The app thus makes consumers constantly aware of how much energy they are actually using rather than waiting to get a bill many weeks later. When customers keep track of their daily energy use in this way, their behavior tends to change and, on average, they save between one and five percent. This is also important for power companies. For example, lower demand of this order might lead to changes and, on average, it would also stabilize the grid. In October 2014 Siemens launched a cooperation project with the Augsburg (Germany) municipal utility company. The project is being conducted as part of the BayKET project for innovative energy technologies and energy efficiency and receives support from the Bavarian Ministry of Economics, Media, Energy and Technology. The project’s partners want to build a prototype superconducting fault current limiter by the end of 2015. The current limiter will be installed on the grid of the Augsburg municipal utility company and a facility operated by MTU onsite energy (MTU), which manufactures cogeneration plants.

**Ice Cold Current Limiters**

Because more and more solar facilities and wind farms are feeding energy into the grid, a short circuit could cause extremely strong currents through power lines and destroy grid technology. Researchers at Siemens want to prevent this by developing superconducting fault current limiters. These systems would not only be reliable, they would also stabilize the grid. In October 2014 Siemens launched a cooperation project with the Augsburg (Germany) municipal utility company. The project is being conducted as part of the BayKET program for innovative energy technologies and energy efficiency and receives support from the Bavarian Ministry of Economics, Media, Energy and Technology. The project’s partners want to build a prototype superconducting fault current limiter by the end of 2015. The current limiter will be installed on the grid of the Augsburg municipal utility company and a facility operated by MTU onsite energy (MTU), which manufactures cogeneration plants.

**Power Plant Breaks Three World Records**

The combined cycle gas turbine (CCGT) power plant at the Lausward location in the port of Düsseldorf, currently under construction and due to enter service in 2016, is aiming for no less than three world records. It will have an electrical output of 595 MW, the highest ever for a single combined cycle unit; its net energy conversion efficiency will add up to more than 61 percent; and for the first time it will be possible to extract 100 MW of thermal energy from a single power plant unit in combined cycle operation. In this way, the overall efficiency of natural gas as a fuel rises to 85 percent. The heart of the Lausward CCGT power plant’s fortress is an extremely powerful SGT-800 gas turbine from Siemens, which has already sold 40 times around the world and is now in commercial use on three continents. Highly efficient and flexible CCGT power plants ideally complement renewable energy sources such as the wind and the sun, which are subject to fluctuations in their power output.

**Three World Records**

Highly efficient CCGT power plants ideally complement renewable energy sources such as the wind and the sun, which are subject to fluctuations in their power output. Siemens is aiming for no less than three world records. It will have a total output of 595 MW, the highest ever for a single combined cycle unit; its net energy conversion efficiency will add up to more than 61 percent; and for the first time it will be possible to extract 100 MW of thermal energy from a single power plant unit in combined cycle operation. In this way, the overall efficiency of natural gas as a fuel rises to 85 percent. The heart of the Lausward CCGT power plant’s fortress is an extremely powerful SGT-800 gas turbine from Siemens, which has already sold 40 times around the world and is now in commercial use on three continents. Highly efficient and flexible CCGT power plants ideally complement renewable energy sources such as the wind and the sun, which are subject to fluctuations in their power output.
Dynamic Grids Take Shape

Smart grids support network stability by helping to establish a balance between power generation and demand. In conjunction with energy storage devices, they enable distributed energy producers to be integrated into the grid on a large scale.

Energy generation once was a simple matter of having power stations produce electricity that was consumed by households and industry. Rooms were kept warm with gas or oil heating systems and cool with air conditioners. Energy suppliers had to maintain power stations that produced electricity on a large scale. Today, however, energy consumption is becoming more complex, and it is becoming necessary in order to safeguard the transmission and distribution of electricity from a growing number of fluctuating sources. They help to increase energy efficiency by incorporating prosumers (examples include buildings and, in the future, electric cars) and balancing supply and demand as much as possible.

Safe Networks for Energy Ecosystems. Smart grids are particularly important for the sustainable management of energy in urban areas. They require all of the electricity market’s components to communicate with one another, and they incorporate large as well as small decentralized power generation units and consumers into an overall structure. Smart grids regulate power generation and prevent network overloads by ensuring that only as much electricity is produced as is actually needed. In addition, demand management processes can be used to minimize peaks and balance energy supply. For example, cooling systems can be shut off for short periods; elevators can travel more slowly, and industrial power demand can be scheduled to take place when energy supplies are at their highest levels. Throughout the world, Siemens is already using smart grids to optimize the balance between the supply and demand of electricity.

The Road to Energy Storage. Electricity generation from renewable sources fluctuates with weather conditions. Researchers are doing everything they can to minimize this drawback — among other things by using machine learning to provide gigantic wind turbines with an element of intelligence so that they can continually optimize their electricity output (p. 48). Despite these improvements, energy storage devices will increasingly be needed to store surplus electricity from the smart grid for hours, days, and even weeks, if necessary. Pumped-storage power plants are a proven storage technology with a high level of efficiency. They use surplus electricity to pump water into a higher-lying basin. When more power is needed, the water flows downward to drive turbines that generate electricity. Unfortunately, there aren’t enough places that are suitable for pumped-storage power plants — at least not near densely populated urban areas.

That’s why Siemens is working on the development of alternatives. One storage solution that is already available is Siestorage. This modular system buffers short-term — seconds or minutes-long — fluctuations in output from renewable energy sources. Siestorage is based on lithium-ion rechargeable batteries, and the large version of the system fits into a standard shipping container. It can store 1,000 kilowatt hours of electricity, which is about the average daily power demand of 100 households.

Large-Scale Electrolysis-Based Hydrogen Production at the Mainz Energy Park

A large-scale pilot project has been under way in Mainz, Germany, since May 2014. At the Mainz Energy Park, project partners Siemens, Linde, the Mainz municipal utility company, and the RheinMain University of Applied Sciences are jointly developing an electrolysis facility that will produce large quantities of hydrogen in 2015. The facility will use electricity generated from neighboring wind turbines and other sources. The hydrogen will be stored, transferred to tank trucks, or fed into the natural gas network so that it can later be used to generate heat or electricity. The Energy Park’s overarching goal is the development, testing, and use of innovative electrolysis technologies for the production of hydrogen using energy from renewable sources. At the heart of the facility will be a building equipped with a hydrogen electrolysis system developed by Siemens. The facility will differ from other, much smaller pilot plants in that it will be supported with a highly dynamic PEM high-pressure electrolysis unit. The latter will be the largest electrolysis system of its kind in the world and will consume up to six megawatts of electricity. As a result, the facility will have sufficient output to offset bottlenecks in the grid and at small wind farms. The project encompasses investments of about €17 million and is supported by the German Federal Ministry for Economic Affairs and Energy as part of its Energy Storage Funding Initiative.

Find out more about electrolysis-based hydrogen production at:
www.siemens.com/pof/electrolyser
Italy’s Model Microgrid

Siemens and researchers from the University of Genoa have built a smart grid at the university’s campus in Savona. The grid uses a combination of conventional and renewable energy sources, as well as energy storage devices. The project has already significantly lowered the university’s electricity costs.

A metal parabolic reflector that rises up to the blue sky looks like a giant satellite dish. But instead of receiving signals from television stations around the world, it captures energy from the sun and concentrates it at its focal point, where a circulating liquid is heated. Along with CO₂-free concentrated power, it captures energy from the sun and its thermal system, the SICAM PAS, which is based on Siemens’ DESIGO building management system, visually depicts the entire grid, and controls all components and visually depicts their status and condition.

The centerpiece of the SPM is the SICAM PAS grid management system, which links Siemens’ Decentralized Energy Management System (DEMS) and the SICAM PAS solution. DEMS uses smart meters to monitor all energy flows in real-time and ensure the optimal operation of all energy generation units and devices. In addition, it can produce energy-demand forecasts with the help of historical data and current information. It also uses weather forecasts to make predictions regarding the expected yield from renewable energy sources. These predictions are accurate 80 percent of the time and thus enable the system to plan gas turbine operations in advance. When supplies are sufficient, DEMS uses renewable energy to recharge the SPM’s energy storage devices in order to further reduce energy costs. “Control and management are particularly demanding because we need to simultaneously optimize an electrical and a thermal system,” Delfino explains. “Our SPM is an internationally pioneering project in this respect as well.”

Keeping an Eye on Entire Facilities. One of the biggest challenges in the project was to ensure that all data from system components could be centrally collected and stored. Although the IEC 61850-7-420 standard defines a communication protocol for smart grid components, the manufacturers of low-voltage equipment prefer to use simpler standards, which means the associated devices, sensors, and actuators initially didn’t share a “common language.” Another problem was that most of these components were designed to be used with proprietary monitoring tools and could not easily be made to work with a central SCADA program. SCADA, which stands for supervisory control and data acquisition, consists of computer systems that monitor, visually depict, and control entire facilities. Siemens, which is based on the SIMATIC WinCC platform from Siemens, is used in Savona. The system monitors and controls all components and visually depicts their status and condition.

Cutting Energy Costs. Researchers are extremely satisfied with the results of the project, which has been up and running for nearly a year. The university is definitely benefiting as well. “We are already producing half of the energy we need,” says Delfino. “Moreover, SPM’s design will allow us to integrate even more renewables in the future, which will enable us to produce all the energy the campus needs. Such self-sufficiency is important, especially in areas where there’s no public grid or where the grid is weak. Our energy bill has also decreased from €300,000 to €200,000 per year, and our CO₂ emissions have declined from 820 to 700 tons per year.” Bernd Koch, who is responsible for expanding microgrid business activities at Siemens, also believes there are no longer any obstacles standing in the way of commercializing smart grids. “In Savona, we used off-the-shelf components,” Koch says. “The algorithms used to operate the system are very reliable, and in general the SPM has met our expectations and in some cases clearly exceeded them.” In order to bring the new technology to market as quickly as possible, Siemens is also participating in other reference projects — for example, at the British Columbia Institute of Technology in Vancouver and at Newcastle University in the UK.

Soon, the general public will have a chance to find out more, as smart grids will be a part of Expo 2015 in Milan, which will run from May 1 to October 31. Italian energy company Enel will use Siemens technology to set up a smart grid at the Expo site that will cover all pavilions, the transmission network, and charging stations for electric vehicles. Smart meters will provide data on energy demand in real-time, a SCADA system will control and visually depict the entire grid, and Siemens’ DESIGO building management system will optimize energy demand at all pavilions. There will also be a Smart City Control Centre that demonstrates energy distribution and integration in entire cities will be optimally managed in the future. Christian Buck
Smart Grids — The Perfect Base for Innovative Services

Italy is considered to be the world’s leading country with regard to the introduction of smart meters. Where are such meters being used? Cinotti: The first smart meter for electric energy consumption was installed in Pisa in 2001. Italian regulations established in 2007 that 95 percent of low-voltage grid connection points rated less than 55 kW should be monitored by a smart meter by the end of 2011. I think that this challenge has been met. At the end of 2011 there were 33 million connected smart meters in Italy, and now there are approximately 36 million for a population of 60 million. Thus Italy is in the lead with respect to the EU road map, which calls for 80 percent coverage by 2020. The smart meters serve all sectors — the public and the private sectors, industry, agriculture, and the services sector.

What are Italy’s plans for the future? Cinotti: Smart metering is now being extended to gas. Specifically, targets for intelligent gas meters are to achieve 3 percent coverage by the end of 2014 and 60 percent coverage by 2018. Eventually smart water meters will also be deployed.

How willing are Italians to invest money in advanced energy technologies for buildings? Cinotti: Italians have traditionally been less sensitive than Germans to the need for an energy transition because of our mild climate, which keeps the per capita energy bill relatively low. But recently we have started to become increasingly conscious of the need to increase energy efficiency because of rising end user energy prices. Furthermore, tax incentives are making investments oriented to energy efficiency attractive for private investors and homeowners. Therefore I’d say that the will to invest in emerging energy technologies is currently growing quite fast. This is also having a healthy impact on the construction industry. In existing buildings, investments mostly address thermal insulation solutions, while electricity-related investments in CHP (combined heat and power) are becoming popular in new buildings, mostly because of support programs but also partly because of their trendy appeal. Electric cars, e-bikes, and e-motorcycles are also likely to be the subject of growing interest as means of personal mobility over the coming years.

What is the “smartness” of the smart grid being used for? Cinotti: The convergence of energy and information — in other words, the “smartness” of smart grids — is a crucial factor in the effort to reduce emissions, lower operating costs, decrease energy imports, increase energy efficiency, localize energy usage, and bring in new services and better energy quality. For example, a smart meter network facilitates the deployment of all sorts of innovative services while drastically decreasing the costs of running the grid. For instance, smart control of energy congestion helps to maintain energy quality in the presence of large and highly intermittent loads and generators such as those originated by future bidirectional fast chargers, enabling in this way electric mobility penetration in smart cities. In the future, we may expect the smart grid to have a growing impact.

Interview conducted by Susanne Gold

Why Finland Has Europe’s Most Advanced Grid

Are there regions in Finland where a smart grid has already been installed? Segerstam: The Finnish grid is a smart grid, version 1.5, which makes it the most advanced grid in Europe. Version 1.0 came about some years ago with network-controlled loads and remotely controlled disconnectors. When smart meters and control relays were rolled out to all Finnish homes in the last couple of years, we reached version 1.5. Now we can connect, disconnect, and monitor any site anywhere in Finland. Sites with electric heating can be managed with discrete control calendars that enable dynamic pricing with automatic load control. All of the meters are able to register feed into the network, allowing for the rollout of distributed generation devices. All site measurements are collected, distributed, and used in the market and balance settlement every day for every hour on a rolling basis.

If this is Version 1.5, what will Version 2.0 look like? Segerstam: A smart grid Version 2.0 would allow for dynamic grid areas and energy communities to form around shared resources and would incorporate even more dynamic load and generation devices that would be available for the creation and provision of new services. Status and quantity information should be available with the shortest possible delays, allowing for new market designs to be created and implemented.

Your company’s slogan is “Building a Smarter Society.” What do you wish to express by it? Segerstam: Empower is a company that is involved hands-on in the creation of the flexible energy system of the future. This means that we are in the field building the infrastructure of the future, and we incorporate smart technologies. Empower Information Management (IM) delivers systems that enable people to use services efficiently and serve the flexible energy market. Empower Industry enables the operation and maintenance of industrial facilities and provides new ideas for energy generation and use in industrial processes. In recent development projects Empower IM has worked with partners such as Siemens to create many new service concepts that enable future business models around issues such as smart buildings, electric vehicle infrastructures, and access to the energy market for buildings and homes.

What do buildings still need in order to be even more sustainable? Segerstam: Many buildings would benefit from smarter control of the energy resources they have. Commercial and industrial sites have used building automation for a long time, but so far very few have combined the opportunities of the energy market with the control opportunities inherent in their processes. When renewable energy sources like wind and solar power are included in the equation, many new opportunities arise. By combining the innovative building control systems created by Siemens with the cloud services and interfaces available through Empower IM, commercial and industrial sites could harness many opportunities.

Interview conducted by Susanne Gold

Read the full-length version of this interview in PoF Digital:
www.siemens.com/pof/cinotti

Read the full-length version of this interview in PoF Digital:
www.siemens.com/pof/segerstam
Machine learning helps make complex systems more efficient. Regardless of whether the systems in question are steel mills or gas turbines, they can learn from collected data, detect patterns, and optimize their own operations. Researchers at Siemens have demonstrated that continuous learning also allows wind turbines to increase their electricity output.

On his free time Volkmar Sterzing likes to work as a sailing instructor on Lake Starnberg south of Munich. A specialist in machine learning at Siemens Corporate Technology, Sterzing says that, “There are definitely parallels between sailing instruction and the machine learning process we use to optimize products.” Whereas his pupils learn to understand the power of the wind so intuitively know when and how they have to set their sails, Sterzing studies how complex systems such as wind turbines can independently recognize regular patterns in collected data and thus learn how to optimize their operations.

Optimizing Complex Systems. Siemens engineers have been studying machine learning for the past 25 years. “The associated processes offer many possibilities for making systems smarter and more efficient,” says Professor Thomas Runkler, an expert in machine learning at Siemens Corporate Technology in Munich and a professor at the Technical University of Munich. “Siemens has used machine learning to optimize industrial facilities such as steel mills and gas turbines.” Machine learning can also be used to reliably forecast the prices of energy and raw materials or to predict energy demand in entire regions.

Neural Networks at Work. A precondition for machine learning is the availability of computer systems that can learn from vast quantities of data and optimize their behavior accordingly. Among other things, Sterzing is studying how machine learning enables wind turbines to adjust themselves to fluctuating wind and weather conditions in order to increase their electricity output.

Wind turbines optimize their output by comparing their operating data with weather data,” says Sterzing. Sensors and in on such systems routinely record data regarding the direction and speed of the wind, temperatures, electric currents and voltages, as well as vibrations produced by major components such as the generator and the rotor blades. “Previously, these sensor parameters were used only for remote maintenance and service diagnostics. But now they are also helping wind turbines generate more electricity,” says Sterzing.

Using neural networks, researchers at Siemens spent four years analyzing and modeling various dependencies and interrelationships. Neural networks are the key to successful machine learning in wind turbines. “Neural networks are computer models whose operations are similar to those of the human brain,” explains Sterzing. They learn from examples, recognize patterns, and use past measurement data to make forecasts and ideal models regarding the future behavior of complex systems.

This is particularly applicable to wind turbines. On the basis of past measurement data, software calculates the optimal settings for various weather scenarios that involve a variety of factors such as sunshine duration, hazy conditions, and thunderstorms. The data is transmitted to the wind turbines’ control units, which take it into account from then on as they adjust their functions. If familiar wind conditions arise, the control units immediately use the optimal settings that were ascertained as a result of machine learning. This can result in the adjustment of rotor blade angles, for example. “As a result, turbines become more and more efficient and produce more energy,” says Sterzing.

This could further reduce the costs of wind energy in the future, and that’s an important consideration, given that wind turbines are becoming more and more competitive compared to conventional energy generation systems.

The ALICE Research Project. In the ALICE (Autonomous Learning in Complex Environments) research project, experts from Siemens, IdaLab GmbH, and the Machine Learning group at the Technical University of Berlin collected information on how to optimize wind turbines. The project, which was funded by Germany’s Ministry of Education and Research, was completed in June 2014. Wind turbines demonstrated their learning abilities in field tests that were held as part of the project. In 2013, tests were conducted with up to eight turbines at two small offshore and onshore wind farms in Spain and Sweden. The wind power systems learned by using their own measurement data and achieved a noticeable increase in efficiency. However, it is still not quite clear by how much the efficiency increased, so additional larger-scale research projects are needed.

“Fall away!” Sterzing suddenly shouts out toward the lake. One of his pupils is sailing too close to the wind to reach the windward practice buoy. Even though he is sailing a shorter distance than the other pupils, it nonetheless takes him longer to get to the buoy because he is traveling more slowly. “The kids are learning how their boats behave in different weather conditions, and what they have to do in response — and our wind turbines are learning something similar,” Sterzing says.

Sterzing looks out over the lake. With great satisfaction, he observes that one of his pupils is now among the first to sail around the windward buoy. “Learning pays off,” he says with a grin, thinking not only of sailing but also of Siemens. After all, Volkmar Sterzing’s hobby is very closely connected to his profession.
Turning Carbon Dioxide into Raw Materials

Researchers at Siemens are developing a system that uses surplus energy from renewable sources to convert carbon dioxide into carbon compounds for industry. Their vision is to eventually manufacture modules that would cover buildings, concentrate ambient carbon dioxide, and produce chemicals such as methanol from sunlight.

example, into methane, the energy-rich gas that is the main component of natural gas, or into carbon monoxide, which can be used to produce fuels such as ethanol.

Exploiting Carbon Dioxide. Plants exploit carbon dioxide by absorbing light energy using pigments such as green chlorophyll. This process releases energy-rich electrons in the chlorophyll. Enzymes then transfer these electrons to CO2, which becomes chemically active and reacts with other compounds. A number of teams are trying to completely replicate photosynthesis, especially in the United States and Japan," says Prof. Maximilian Fleischer, who manages synthetic photosynthesis research at CT, as part of a project known as "CO2toValue." "But this is currently almost impossible to achieve, due to its complexity. That’s why we are taking a more pragmatic approach, in which we are gradually getting closer to achieving photosynthesis in a number of steps. Such an approach is necessary if you want to quickly launch a product on the market."

As a result, Fleischer and chemists Günther Schmid and Kerstin Wiesner, as well as about ten others, are not yet trying to capture light. Instead, they are focusing on activating CO2 and converting it into products. To do this, they are using electricity generated from renewable sources.

Working with Universities. The key elements of the CO2toValue project are chemical catalysts that charge inert CO2 with energy-rich electrons. The challenge is to charge only the carbon dioxide with electrons and not surrounding water molecules, because the latter would merely result in the production of conventional hydrogen. Specialists at the University of Lausanne in Switzerland and materials scientists at the University of Bayreuth in Germany are working with Fleischer’s team to develop catalysts on behalf of Siemens. This work has already led to the creation of a variety of catalysts, some of which contain copper, which have high yields of products such as carbon monoxide. The development of such catalysts is challenging work because their behavior can only be partially predicted. As a result, each new catalyst must be examined in a long series of tests and under a variety of conditions. Another factor to be considered is that a catalyst’s effectiveness is partly determined by its surface structure. That’s why its manufacturing process must be carefully controlled to create a highly reactive surface resembling a miniature craggy mountain.

The trick now is to manufacture the cathode, the negative pole of the special catalyst, in such a way that it is able to transfer electrons directly to the CO2 in order to produce the desired product. The water in the module is separated into hydrogen and oxygen at the other pole. The hydrogen is needed to create hydrocarbons, and the oxygen released during this process can also be used, depending on which product is desired. The carbon dioxide in the water is initially blown into the electrolysis cell from a gas cylinder at the lab. This process already works very well for the production of carbon monoxide, with 95 percent of the electricity being used to produce the carbon monoxide," explains Fleischer. By selecting appropriate catalysts and changing the current density or the salts that are dissolved in the water, researchers can precisely control the reaction and make it convert the CO2 into ethylene or carbon monoxide, for example. Fleischer primarily focuses on creating high-quality substances that are needed by the chemical industry. What makes these substances particularly interesting is that today the chemical industry is still almost wholly dependent on raw materials derived from petroleum.
**CO₂ extraction modules could cover building facades and convert the gas into biofuel.**

"Of course we could also produce methane gas, but it wouldn’t be a profitable business model because you can obtain it much more cheaply from natural gas," says Fleischer. However, a manufacturing facility would pay off if it produced sought-after chemicals such as carbon monoxide, ethylene or alcohols. These currently cost between €650 and €1,200 per metric ton, and many millions of tons of them are needed every year. A large-scale demonstration facility is scheduled to go into operation in Fleischer’s lab as early as 2015. Unlike the current facility, the new one’s output won’t be measured in watts, but in kilowatts. By then at the latest, Fleischer wants to capture the power of the sun. He is thinking of having the photosynthesis occur in glass modules similar to photovoltaic cells. Light would stream in from the top, while carbon dioxide would flow into the system from the bottom. Fleischer has also determined how this “light trap” would work. Instead of trying to imitate complex chlorophyll molecules, Fleischer would use “light-collecting grains” based on semiconductors. These grains would be enveloped by catalysts. If everything goes as planned, the semiconductor would supply energy-rich electrons, which the catalyst would then transfer to CO₂ in fractions of a second. The entire process would be driven by light.

Such a system is expected to be ready in about two years. Depending on the application, the facility of the future will initially use CO₂ from the exhaust produced by power stations, factories, and chemical plants. Subsequently, however, it will use CO₂ from the atmosphere. With a view to accomplishing this, researchers are developing materials capable of absorbing CO₂ like a sponge – and thus concentrating it. This would allow production of methanol, a valuable biofuel. Fleischer considers these prospects very tempting. "The modules could cover building facades, where they would extract CO₂ from the air and from exhausts — and turn it into fuel," he says.

Synthetic photosynthesis is a fascinating concept — even in the current initial stage, when it lacks any light-collecting ability. Fleischer believes that it could be used to store energy from renewable sources. "On windy and sunny days, Germany already has more electricity generated from renewable sources than it needs. What it lacks is sufficient energy storage capacity," he says. "However, if the electricity were fed into photosynthesis modules, it could be used to produce valuable chemicals. This would help to reduce demand for petroleum and thus cut greenhouse gas emissions. What’s more, human beings will have incidentally managed to imitate the most productive chemical process on Earth. The dream of operating biochemical factories efficiently with sunlight could become a reality."

— Tim Schroeder

---

**Carbon Dioxide Conversion to Commercial Products Via Electrolysis Using Conventional and Renewable Energy Sources.**

**First proof points demonstrated for a device that uses excess renewable electricity & stored CO₂**

**A visionary option is being investigated that might eventually directly utilize sunlight to drive the process**

**In an electrolytic process, highly conductive carbon dioxide-rich water is exposed to an electrical current from electrodes. A specialized catalyst ensures that the right final product is produced.**

---

**Swarm Solution for Energy Users**

Caterva, a young company that Siemens helped to establish, is empowering energy consumers. Participants in a Caterva pilot project can use the lion’s share of the solar power they generate themselves while collectively storing enough power to help stabilize the grid.

If Germany succeeds in its energy transition, energy storage systems (ESS) such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants, such as quick-start gas-fired power plants. However, Caterva, a young Munich-based company, is demonstrating that there is also another way. "Caterva is the Latin word for swarm," says the company’s managing director, Markus Brethler. The swarm principle is simple, and involves storing the electricity produced by photovoltaic modules such as those on the roof of Seubert’s home in lithium-ion batteries. Each cabinet of batteries has a total output of 20 kilowatts and a capacity of 21 kilowatt-hours (Wh). Cabinets in buildings throughout a region are connected through the grid, creating a swarm or virtual storage system with an output of over one megawatt. The cabinets are controlled via mobile radio, and electronic systems in the cabinets allow a control center to tap or recharge Caterva participants’ batteries. If there is demand for additional electricity in the grid, the control center draws power from the swarm of batteries.”
Best of Pictures of the Future | Spring 2015

Energy storage systems enable private solar panel owners to use more of their own power.

The Caterva solution consists of lithium-ion batteries (left) and a mobile communication network. When linked with units in other buildings, they form a virtual storage system. 

see box page 55), and then enhanced by var-
ious departments at Siemens Corporate Tech-
nology until the basic version of the swarm software was completed. Experts at SNB also helped establish Caterva, because it is their job to create a promising business idea cannot be further developed by Siemens AG as well, or quickly, or on its own.

Before becoming the managing director of Caterva, Brehler gained extensive experi-
ence at another Siemens spinoff, EnOcean GmbH. Siemens will continue to support Caterva in many ways in the future. For exam-
ple, it connects the cabinets to all of the hardware and is also a minority shareholding in the company.

Pilot Test. Several months ago, in coopera-
tion with energy supplier N-Érge, Caterva launched a pilot test in which about 65 pri-
ivate photovoltaics owners will eventually take part. Banks of batteries in their homes enable these consumers to consume more of their own electricity than they would without such an energy storage system — between 60 and 80 percent on average compared with 30 percent, which would otherwise be the case.

Seubert, a 52-year-old sector manager for packaging machines at Siemens, is the first person to take part in the project. When he and his family moved into their new home in the little town of Dettelbach in the fall of 2013, he installed solar panels on the roof as a matter of course. The panels produce vast amounts of electricity on sunny days, and Seubert was annoyed that he could use rela-
tively little of it himself. Although the elec-
tricity supplier would have collected the en-
tirely on grid. Seubert was paid for it, his long-
term goal was to become independent of energy supply. He thought it would be unprofitable for him to buy the batteries for storing the solar power. “Experts advised me against it, be-
cause they still consider high-performance batteries to be too expensive for private householders,” he says. By chance, he found out about the Caterva project. “My colleagues at Siemens who are working on technologies that could complement the energy supply system,” says Seubert. After he registered to take part in the pilot project, quickly agreed to form a partnership and also brought Friedrich Alexander University (FAU) in Erlangen on board. Scientists from the uni-
versity will support the pilot project until 2017. “We can now gain experience for a time in the future when more and more elec-
tricity will be obtained from renewable en-
ergy sources,” says Sigert.

Positive Response. Each project partner is responsible for specific tasks. N-Érge con-
tacts customers in its grid area who have rela-
tively new solar panels installed on their roofs. “The response has been very positive. We quickly found more than 25 potential par-
ticipants and expect to find the rest soon,” says Sigert. Caterva is the contract partner for the participants. It supplies them with the system for the steel cabinet and connects it to the network. “Participants pay a single registration fee for this service. They benefit from an important advantage to around €4,000 during the pilot phase,” Brehler explains. Households recoup this through the difference between the amount that they would have to pay for electricity from the grid in Germany — currently about 27 euro cents per kilowatt hour — and what they could pay if they use the electricity themselves, which is around 16 euro cents per kilowatt hour.

At the same time, the ESS units “know” when the grid frequency fluctuates due to an imbalance between the supply and demand for electricity. This is the case, for example, when the distributed power producers gen-
erate too much electricity or when conven-
tional producers such as power plants break down. In such situations, electricity has to be immediately fed into or taken out of the grid so that the difference between electricity pro-
duction and consumption can be offset and grid frequency kept at 50 hertz. This is tradi-
tionally done by conventional power stations such as gas-fired power plants.

Since 2011 Germany has also allowed dis-
tributed energy producers to perform this task, provided they feed at least 1 megawatt of controlling power into the grid. In its sys-
tem services roadmap for the year 2030, the

German Energy Agency (dena) plans to have more and more distributed producers take over this task. But before that can happen, Germany will have to test and use new tech-
nologies such as those from Caterva. “We have to act now so that we will have solu-
tions to keep the grid stable five years from now,” says Brehler.

Swarm Coordination. Participants in the pilot project not only benefit by consuming more solar power themselves; they are also helping to make the energy transition a suc-
sess. The participants’ ESS units are unit-
mated by a Caterva app, which always displays the household’s electricity consump-
tion and the photovoltaic system’s output as well as the amount of energy that is stored in the basement battery or fed into the grid. However, the participants have no control over the batteries in their basements. All of the data is transmitted to the N-Érge control center. “The data is of course encrypted and made anonymous,” says Sigert. “The control center determines when the swarm batteries supply electricity for controlling power and how much.” It does so according to clearly specified rules so that the households’ energy needs are met at the same time that the con-
 trolling power is supplied.

This pilot project, which was only recently launched, is just the beginning of a fur-
ther development. N-Érge is thinking of inte-
grating owners of photovoltaic systems from all over Germany, because “the bigger the swarm, the bigger its contribution to grid sta-
bility,” says Sigert. Germany is especially well suited for the implementation of this swarm concept, whose slogan is “Mit der Sonne im Netz” (Into the grid with the sun). At approx-
imately 1.7 million, Germany has far more owners of private photovoltaic modules than any other country in the world — a figure that highlights the potential opportunities for new business concepts associated with the energy transition. Markus Brehler is con-
vinced of this as well. “We are now looking for financial investors who are inter-
ested in business models for future energy concepts,” he says.

But that’s still a long way off. For now, Seubert is satisfied that the system in his basement works reliably. “I hope that I will only have to take care of the system in the long-
term even if there is a widespread power out-
age,” he says. “I would even be satisfied if I could watch my energy production on a soccer game on TV.” That should already be possible today.

Katrin Nikolaus
The New X-Ray Revolution

Making blood vessels visible without contrast agents; differentiating tumors more clearly from healthy tissues — and doing it all with low radiation doses and large energy savings. These are the objectives of a new generation of X-ray systems from Siemens' laboratories.

What happened on November 8, 1895, late one Friday evening in the Physics Institute of the University of Würzburg can doubtless be described as one of the most revolutionary developments in the history of medicine. Wilhelm Conrad Röntgen discovered a "new type of radiation" that seemed able to penetrate material with ease, and he quickly recognized how useful this type of radioscopy could be for medical practice. Before Christmas, he succeeded in making the first "X-ray photograph." It was an image of his wife's hand, in which not only her wedding ring, but also her bones were clearly visible. The fact that Röntgen was awarded the first Nobel Prize in Physics in 1901 was only a logical consequence of his groundbreaking achievement.

It wasn't long before the first commercial products appeared. On March 24, 1896, just three months after Röntgen's discovery, the company Siemens & Halske obtained a patent for a new X-ray tube that was "especially suited to translumination of the entire body of adult persons." And to this day, Siemens has remained faithful to diagnostic radiology. The company offers a wide range of solutions, from mobile devices to fully digital systems, to CT scanners for 3D images.

The Shortcomings of X-ray Systems. Over 90 percent of all medical imaging examinations worldwide now rely on X-rays. But the technology is still based on the fundamental principle that was used 120 years ago: electrons that are generated in a cathode and accelerated to high energies collide with a solid anode — usually made of the heavy metal tungsten — and thereby release X-rays. The X-rays, in turn, are absorbed to a greater degree by bone than by soft tissue. Bones therefore appear darker in an X-ray image, while soft tissues appear lighter.

Despite the success of this technique in medical engineering, it does have a few drawbacks. For example, the electrons that collide with the anode mainly produce heat, and no more than one percent of the energy is converted to X-rays — a huge waste. There are also many applications, such as tumor diagnostics, in which physicians want to be able to distinguish among various soft tissues more easily. But if contrast is increased, the patient is exposed to a higher dose of X-ray radiation — which should be avoided, because high radiation doses can damage tissue. In X-ray examinations involving cardiovascular diseases, on the other hand, contrast agents are often needed in order for angiography systems to be able to make blood vessels visible in X-ray light — but nearly one out of ten patients suffers allergic reactions to these substances, which can lead to shock and kidney failure. A technique that uses smaller quantities of contrast agent, or even none at all, would therefore be beneficial to millions of people.

New Revolution in Medical Diagnostics. "The technology we're currently developing at Siemens could help us overcome all these challenges," says Prof. Oliver Heid, head of the Global Technology Field of Healthcare Technology and Concepts at Siemens Corporate Technology. Heid is a medical doctor and holds approximately 100 patents in a large variety of fields, from high-frequency technology to superconductivity, materials science, accelerators and software solutions. "We're in the process of completely rethinking everything and changing everything — the method by which X-rays are generated as well as the technique used for detecting them. If everything goes well with our next-generation X-ray system, it will be another achievement in medical diagnostics," says Dr. Heinrich Kölem, CEO for Angiography and Interventional X-Ray Systems at Siemens Healthcare.

This multi-year R&D project, which is scheduled to run until 2017, brings together just the right innovators. Alongside Heid and Kölem, it includes the Components and Vacuum Technology team at Siemens Healthcare, which is led by its CEO Dr. Peter Marz. Also involved are researchers from Siemens Corporate Technology in Russia, external partners from institutions such as Oxford University, as well as Prof. Alessandro Olivo of University College London, whose contribution to the development team includes both scientific expertise and insights from clinical practice. Molnar, whose business unit produces approximately 22,000 X-ray tubes per year for CT machines, angiography systems, and X-ray equipment from Siemens, underscores the value of this cooperation. "Our shared objective is to commercialize the new system in a competitive form and successfully launch it on the market. Only then does a good idea become a true innovation," he says.

Substantially Higher Energy Densities. What exactly is being changed? It starts with the cathode. Here, the team is no longer using 2,000-degree Celsius filaments to emit electrons. Instead, they are using a ring-shaped "cold cathode" of nanostructured carbon that operates at a high voltage and at room temperature. The advantage of this approach is that it uses less energy than previous cathodes.

Electrons no longer collide with a solid target of tungsten, but with a new device invented by Siemens researchers that they've named LiMA, which stands for "liquid metal anode" target. In other words, the electron target is a jet of liquid metal as thin as a human hair. The metal consists of 95 percent lithium and 5 percent heavy elements such as bismuth or lanthanum. The latter produces a short wavelength X-rays, the former acts as a coolant. The energy of electrons leaving the liquid-metal-jet anode can potentially be reclaimed and fed back into the energy cycle. The result is that the X-ray tube requires less than half the electricity and cooling of previous devices, which greatly reduces total energy demand.

Significantly more important, however, is the fact that the tube can achieve a much higher energy density at the target. At the same output, the focus of the new X-ray source is 400 times smaller than in conventional X-ray tubes — "at the focal point, this X-ray beam is as fine as a hair thinner than the sun on the surface of the earth," says Heid, "which results in a 20-fold higher imaging resolution."
**Phase contrast imaging would make it possible to distinguish different soft tissues.**

A wavefront sensor consists of millions of concave metal or silicon lenses that create a matrix of focal points on the detector. The refraction of the X-ray waves in the object — a tumor, for example — can be determined from the shift of these focal points.

Twenty Times the Resolution of Today's Systems. That, in turn, is the prerequisite for an entirely new imaging technique, one that scientists around the world have been working on for years: phase-contrast X-ray imaging. Whereas conventional radiography simply records whether X-rays penetrate a certain tissue or not, phase-contrast imaging measures the effect that passing through bodily tissue has on the wave phase — i.e. the sequence of wave crest and trough. This physical phenomenon can be seen in the light effects on the bottom of a water-filled swimming pool on a sunny day. This phase shift is highly revealing, since it varies depending on the refractive power of the tissue through which the radiation passes. The approach described here would make it possible to distinguish different soft tissues, in particular fat from water or iron levels in blood, which is essential for being able to easily differentiate a tumor in an early stage of growth from healthy tissue.

"To be able to measure these phase shifts, we're also working on a completely new component on the detector side," says Dr. Andreas Geisler, project manager for the new X-ray system on Heid's team. To this end, a wavefront sensor of the kind used in the arts or astronomy, for example, is to be used for the first time for X-ray light in medicine. The sensor consists of millions of concave metallic or silicon lenses that generate a matrix of focal points on the detector. Through the displacement of these focal points, the refraction in the object can be calculated. This is not possible today with conventional detectors alone.

"So not only will these next-generation X-ray systems be very efficient to operate, they will also do a good job of registering contrasts among soft tissues at a relatively low radiation dose," says Geisler. Blood vessels could be made visible in this way without contrast agents; tumors could be more clearly recognized thanks to the 20-fold higher resolution and phase-contrast X-ray imaging; and the new technology would be ideal for minimally invasive surgery too.

"We want to guide and navigate catheters using magnetic fields, for example, and know at any time via the X-ray imaging where exactly they are located in the body," says Heinrich Kolem. That isn’t possible with conventional X-ray tubes, because they are sensitive to magnetic fields — the next-generation X-ray systems won’t have this drawback, and at the same time, they’ll be able to provide images that are more useful diagnostically.

Ulrich Eberl

Siemens scientists have developed a new software algorithm, which, in combination with a new ultrasound probe, analyzes and visualizes a patient’s aortic and mitral valves in 3D and provides automated measurements in seconds. This information allows cardiologists to quickly evaluate valvular anatomy and physiology with previously unknown precision, thus making therapeutic decisions more objective.

**Personalized Assessment of Cardiac Valves**

Siemens scientists have developed a new software algorithm, which, in combination with a new ultrasound probe, analyzes and visualizes a patient’s aortic and mitral valves in 3D and provides automated measurements in seconds. This information allows cardiologists to quickly evaluate valvular anatomy and physiology with previously unknown precision, thus making therapeutic decisions more objective.

From deep in the chest, somewhere just below the breastbone, a shortness of breath begins to develop and tighten like a vice. Known as dyspnea, this condition may be triggered by mild exertion such as climbing stairs, excitement, surprise, or stress. While dyspnea may be caused by a multitude of underlying diseases and conditions, the challenge is to identify its causes quickly and develop an accurate diagnosis — a prerequisite for optimal and timely therapy.

To accomplish this, Siemens has developed two paired elements: a unique new transesophageal echocardiography (TEE) probe that generates seamless, real-time images of anatomy and blood flow in 4D (three dimensions plus time), and an equally unique new algorithm known as “eSie Valves,” that uses the data generated by the probe to analyze and visualize the acquired image data and derive personalized models of the aortic and mitral valves. Based on machine learning, the algorithm incorporates key data from thousands of annotated images.

In the context of interventional valve therapy such as transcatheter aortic valve replacement (TAVR) and clipping of the mitral valve’s leaflets, this combination of technologies is being focused like a spotlight on key causes of death and quality-of-life impairment. The two most important valvular diseases addressed by these technologies are aortic valve stenosis (narrowing of the aortic valve) and mitral valve regurgitation (a backflow of blood from the left ventricle into the left atrium due to incomplete closure of the mitral valve’s leaflets).

Valvular heart disease, which also includes diseases of the pulmonary valve and tricuspid valve, affects 2.5 percent of the global population. Each year in the United States and Europe roughly 200,000 open heart surgeries are performed in order to repair or replace diseased valves. According to the American Heart Association, in the U.S. valvular diseases are among the most expensive and riskiest cardiac procedures, with an average cost of $164,238 and an in-hospital death rate of 3.63 percent. Advanced imaging may help to improve the diagnostic assessment of diseased patients and thus help to optimize patient management by helping to identify those patients who really need a surgical/interventional therapy and will have a chance to benefit from it.

**Precision Procedures.** As it delivers a comprehensive assessment, echocardiography is the basic imaging method for assessing cardiac status. If significant valvular disease is detected, surgical valve repair or replacement may be indicated. But because both therapies are open heart procedures, many patients cannot benefit from them due to age-related contraindications. In view of this, over the last five years interventional therapies have
become a valid therapeutic option. Such ther-
apies are much more patient friendly com-
pared to open heart surgery. For instance, TAVR in severe aortic valve stenosis and mi-
tral clip therapy in severe functional mitral re-
gurgitation may benefit from Siemens’ new TEE probe, while else Valves may help to im-
prove diagnostic assessment, analyze in-
traprocedural results, and monitor valve prosthesis functions during follow-up.

To visualize a valve’s anatomy and func-
tion, a cardiologist would inch the new trans-
esophageal echo probe down the patient’s esophagus until it was located close to the left atrium. Once satisfied with the images, he/she would record them, and then use else Valves, an advanced analysis semi-auto-
mated software package, to detect the valve by identifying the target object’s position and orientation, as well as landmarks such as key anatomical features. It would then segment (separate) the aortic valve (or mitral valve) from its neighboring structures.

“At that point,” explains Tommaso Mansi, PhD, a Senior Key Expert with Siemens Cor-
porate Technology (CT) who participated in the development of the algorithm that drives else Valves, "the software fits a model of an average valve over the image of the real valve and warps it to follow the borders of the pa-
tient’s actual valve.” The result, he says, is a personalized model of the valve. Finally, the cardiologist clicks “analysis” and else Valves automatically provides key data, such as the annulus diameter, perimeters, areas, etc., which supports interventional planning.

Based on the resulting information, the physician can choose to go to the software’s
dynamic mode, which allows for the visuali-
ization of an entire cardiac cycle. “This helps clinicians to model and measure the valves over time, making it possible, for instance, to see how the diameter of the mitral valve an-
nulus varies throughout a cardiac cycle,” says Mansi, who explains that competing com-
mercial systems are, for instance, capable of showing the mitral valve as a static model in only a single position. “We show both valves dynamically,” he says.

And all of this happens at great speed. “While standard quantification software takes several minutes to provide measurements of one valve in one position,” says Mansi, who worked with Mihai Scutaru and Ingmar Voigt, both from CT, as well as Dr. Razvan Ionasec of Siemens Healthcare, “else Valves provides automated, objective and reproducible meas-
urements of the aortic and mitral valves in

crucial for optimal planning, performance and outcome. Unfortunately, however, this has not always been the case with previous 2D TEE systems. "Until now," says Mansi, "card-
diac surgeons have had to make many of their mitral valve treatment decisions when the heart was open. But else Valves, which is based on real-time 3D TEE data, is now en-
abling highly accurate diagnostic assess-
ment, so that cardiac surgeons will hopefully no longer be surprised by the real anatomy.
In short, else Valves is bringing valvular as-
sessment to a new level of objectivity.”

In addition to the advantages offered by else Valves software, its associated ultra-
sound probe is breaking ground thanks to unique seamless imaging technology. “This is important,” says Helene Houle from Siemens Ultrasound, “the key clinical expert driving the development of else Valves, "because the aortic and mitral valve leaflets move very fast and you do not want to see stitching artifacts in your images, which is something that can happen if the patient is suffering from irreg-
ular heartbeats or an arrhythmia.” She points out that, to get sufficient temporal resolu-
tion, competing systems stitch images from consecutive heart cycles together to produce continuous ultrasound volumes, which have the shape of a pyramid. "Our technology ac-
quires this information in continuous imag-
ing. It simultaneously acquires anatomy and blood flow. The combination of capabilities provided by the new probe – high volume rate, true volume imaging with no stitching in real time and with color Doppler – is unique to Siemens.”

Personalized Picture. While Siemens’ new else Valves technology in conjunction with the recently-introduced real-time 3D TEE probe represents an important milestone to-
ward personalized cardiac care, it is just the first step down the road to a much more am-
bitious vision. What researchers eventually hope to achieve is to model a patient’s entire heart, including hemodynamics – the move-
ment, volume and pressure of blood – and to be able to perform therapies on that person-
alized model with a view to optimizing ther-
apic procedures and minimizing collateral
effects. Clinicians would thus be able to see what the effects of a therapy would be before performing therapy. “The learning technol-
gy behind else Valves is generic,” says Mansi. “This is not just one-shot application. And that is its key differentiating factor. It of-
fers the potential of opening up a world of new applications. It just depends on what you want to apply it to.” - Arthur F. Pease
Underground Economy

2060. In 45 years, many factories will be underground, out of sight, and highly automated. Thousands of humans will compete in a worldwide co-creation environment for cash prizes to design specialized components that can be 3D printed in such facilities or at customer locations.

When Ambrose Turner, a turbine blade manufacturing specialist, is brought back to life after 40 years in an induced coma, he visits the site of his factory and discovers a new world of manufacturing, but also experiences a terrifying encounter with a bionic security system.

Underground Economy

I
t was like experiencing death. The last thing I remember is a truck spinning out of control on an icy road as it raced at me, the shriek of multiple safety system alarms, and the thought that this could not possibly happen – not with all the automated guidance features, the driverless technology, the predictive load-to-road programs, the... No, that was 2020, and it was lights out for me. For forty years I was dead to the world; obliviously suspended in the featureless, automated, insurance policy-financed panorama of an induced coma; one 35-year-old, single, childless turbine blade manufacturer, 62.

Best of Pictures of the Future | Spring 2015

Best of Pictures of the Future | Spring 2015
Scenario 2060

The Future of Manufacturing

look down here, for instance," Zeppy went
starting to piece together a picture of what
nostics, integrated security; you name it,
community hyper-perception, service prog-
particle-spray-field dynamics in additive man-
contracts covering everything from refined
ness. We call it co-creation. They work on
competing against each other for our busi-
more wildlife.

ticed – empty roads, more open space, and
other companies. The result is – as you no-
them around here. Most of them do their
parking lots? Where is everybody?"

Co-creation Workers. "And the workers?" I
peered into the cavernous facility. "You mean
our turbine blades?"

"Yes, sir!" said Zeppy, with a touch of pride

"And the workers? I

"Yes, sir!" said Zeppy, with a touch of pride

"And the workers? I

"Yes, sir!" said Zeppy, with a touch of pride

Co-creation Workers. "And the workers?" I
peered into the cavernous facility. "You mean
our turbine blades?"

Building and disassemble. Instead, the giant
races serve as temporary tourist attractions at
alternating locations. The first of two
record-breaking Ferris wheels is already
at alternating locations. The first of two
rides serve as temporary tourist attractions

The world’s largest transportable Ferris wheel is equipped with control and drive
technology from Siemens. The 750-ton, 80-meter tall steel giant was built by the
Munich-based company Mauser German Wheels according to a plan by Bussink Design.
The 74-meter wide rotatable Ferris wheel rotates two times per hour and can carry up to
16 passengers in each of its 27 gondolas Mobile XL Ferris wheels are not designed
to suit country fairs, as they take too long to

XL Safety Commitment

The world’s largest transportable Ferris wheel is equipped with control and drive
technology from Siemens. The 750-ton, 80-meter tall steel giant was built by the
Munich-based company Mauser German Wheels according to a plan by Bussink Design.
The 74-meter wide rotatable Ferris wheel rotates two times per hour and can carry up to
16 passengers in each of its 27 gondolas Mobile XL Ferris wheels are not designed
to suit country fairs, as they take too long to

Turbine Values in Real Time

In the near future, motion sensors will meas-
ure turbine values regarding wear in gas-fired
power plants. Siemens’ researchers would like
to combine this data with additional informa-
tion and evaluate it in real time. This informa-
tion would cover a variety of parameters, in-
cluding the amount of energy produced and
alterations to electric currents within a motor.
According to conservative estimates, doing so
would reduce the time that technicians need
to access relevant data by at least 25 percent.
Because an average of 80 percent of technician
processing time is spent on collecting data, re-
searchers estimate that over one million Euros
could be saved each year just in the servicing
of turbines. Such real-time analyses are already be-
ing conducted for Siemens’ latest 14-26 gas
turbines, where hundreds of sensors precisely
measure key operating values.

The End of Defects

German Chancellor Angela Merkel
was treated to key elements of the factory of the
future during a February 2016 visit to Siemens’ electronics plant in Amberg, Ger-
many. These products already produce with production machines, and IT systems
control and optimize all processes to ensure the lowest possible defect rate. Siemens is
the world’s leading FV supplier, and the EPA is in the company’s showcase plant for these
systems. Production quality is at 99.9985 percent, and a series of test stations detect
the few defects that do occur. The factory manufactures 12 million Simatic products per
year. At 120 working days per year, this means that the EPA produces one control unit
every second. Production is largely automated. Machines and computers handle 75 per-
cent of the value chain on their own, the rest of the work is performed by people. Only
at the beginning of the machine processing in anything touched by human hands,
when an employee places the initial component (a base circuit board) on a production
line. From that point on, everything runs automatically. What’s notable here
is that Simatic units manage the pro-
duction of Simatic units.

Tomorrow’s Workplace

The factory of the future will be highly flexible and organized like a living Internet in which every-
thing, and everyone, is networked. Tomorrow’s factory jobs will be completely different from those of
today. Although they will continue to be organized around assembly stations, they will not work in
rigid shifts, be subject to inflexible processes, or be restricted to a single workstation. According to
Johannes Schütz and Johannes Labutta, both at Siemens Corporate Technology in Munich, in 15
years most monotonous and strenuous activities will probably be a thing of the past. Schütz and
Labutta focus on the role of humans in production processes. The idea here is to optimally align
an employer’s individual time management with a company’s human resource requirements. Tomorrow’s
factories will be both productive and flexible, meaning that humans will provide flexibility while robots
will ensure fast and efficient production.
From Powders to Finished Products

3D printers are now being used in manufacturing. They are revolutionizing spare parts management and opening the door to new designs for complex components.

Again and again, orange-red flashes sparkle, coming closer, making a couple of loops, and receding again. Olaf Rehme from Siemens Corporate Technology observes the seemingly chaotic whirl of sparks that is taking place behind the window of a 3D printer. He watches a laser beam as it moves along, drawing the cross-section of a component into a layer of powdered metal. In doing so, the laser welds the fine particles of metal together. The platform, on which the component is located, drops lower so that a fresh 0.05-millimeter-thick layer of powder can be spread on top. The laser beam then recommences its dance. Layer by layer, the outline in the dark gray powder grows to become a three-dimensional structure. A virtual 3D model provides the template for the laser’s path. Lasers are increasingly being used in places where objects were previously forged, milled or cast. Laser beam welding creates objects layer by layer. 3D printing has been around since the 1980s. Originally, only rapid-hardening plastic was used for the process, which was ideal for making prototype parts that would later be mass-produced by conventional stamping or injection molding machines. Accelerated Replacement. “But things haven’t stood still,” says Rehme. “Now, 3D printers are not just making the models and molds for individual parts, but the parts themselves. At Siemens, we are even printing burner tips for use as replacement parts for gas turbines.” The all-new technique reduces repair times for certain turbine models by around 90 percent, because the replacement burner tip no longer has to be laboriously welded together. Instead, the new burner tip is simply printed onto the body of the burner, thus substantially reducing repair costs. Some of the parts inside turbines have to operate for a very long time between maintenance intervals. Gas turbine blades, for example, must run for 25,000 hours, despite being subjected to temperatures of around 1,300 degrees Celsius. Plastic parts would be inappropriate for such applications, as they would immediately melt. Siemens therefore prints turbine parts from powdered steel. “We use nickel-based alloys for high-temperature applications in turbines. These types of steel are especially durable and heat-resistant,” says Rehme. Locally Produced Parts. Burner tips are one of many examples of how 3D printing could revolutionize the supply of spare parts. Today, such parts are stored and delivered individually whenever they are needed. In a worst-case scenario, a factory or plant might have to be switched off until an urgently needed part arrives. “In the future, a network of small 3D printers could create spare parts based on digital blueprints. They would make the parts precisely where they are needed: close to the customer,” explains Rehme. New Geometries and Better Turbines. In addition, 3D printing can create shapes that other production methods can’t. For example, it would allow the creation of complex geometries for components that optimally whirl a gas-air mixture to improve combustion. Another example would be the blades in expansion turbines. “Turbine blades contain filigree ventilation ducts to provide cooling,” says Rehme. “At present, such ducts still have to be drilled or cast, but these methods are now reaching their limits. Turbine blades could probably be cooled better if we could print them in one piece.” Better cooling of blades would reduce the amount of cooling air that turbines need, enabling greater efficiency. Extremely High Centrifugal Forces. “However, we have to make more progress before this will be possible,” says Rehme as he takes a brush to sweep the fine powder off of a finished component. “It still takes a relatively long time to print each part. Depending on the object’s size, it can take anywhere from a few hours to several days,” he explains. Rehme and his colleagues also have to further develop the materials used in the printing process. Turbine blades must be capable of withstanding extreme conditions. At high rotational speeds, for instance, the tips of the blades move faster than a pistol bullet and must endure centrifugal forces comparable to the weight of 20 cars. Printed metal parts are still not strong enough to be used under such conditions. As a result, factories will continue to forge, mill, and cast components. This is especially true with regard to mass-produced parts, for which high production speeds and low unit costs are essential. On the other hand, 3D printing will most likely supplement existing techniques, while providing an economical solution for products that must be produced in small batches and unusual shapes. To speed up this process a bit more, the latest printer models include up to four lasers that simultaneously “dance” across a layer of powdered metal.

Andreas Kleinschmidt

See the amazing world of 3D printing in pictures in PoF Digital: www.siemens.com/pof/3d-print
Dr. Ursus Krüger heads Siemens Corporate Technology’s research activities in additive manufacturing.

What is 3D printing?

Krüger: 3D printing is a process that is used to create three-dimensional objects — as though one were printing them. Experts prefer the term “additive manufacturing.” This term is a good description of the revolution that is currently taking place in industry. For thousands of years, objects were manufactured through the removal of material by means of drilling, milling, grinding or chiseling. For example, the statue of David in Florence was hewn from stone. By contrast, 3D printing builds up material additively. This gives product designers completely new options. They can create designs that would be impossible to implement by means of traditional processes. 3D design also makes it possible to realize new functionalities and improve the performance of many components.

In what ways do you expect 3D printing to change manufacturing?

Krüger: 3D printers will increasingly be used in factories. At Siemens they are already being used to some extent, for example at one of our gas turbine plants in Sweden. There, we are printing burner tips for turbines. However, in most cases 3D printing will supplement existing processes rather than completely replacing them — it’s faster to stamp or cast simple components. But when it comes to complex parts, 3D printing will change a lot of processes. The production of individual components and small batches will become more economical and will probably increase.

Which business models could 3D printing fundamentally change?

Krüger: In the future, components with more complex forms will be possible. Sophisticated designs, for example designs that increase the effectiveness of gas turbines, will be easier to implement. And that won’t apply only to large production runs. Because it will be possible to produce individual workpieces more cheaply, it will also be possible to economically provide applications for very special needs. The business of supplying replacement parts could be completely transformed. To date, replacement parts have been produced in advance, centrally stored, and sent out on demand. In the future, replacement parts could be printed out at the customer’s premises. That would save time and money.

What are you working on at the moment?

Krüger: We can already print out a number of things. However, there are very many processes, and each of them has its own strengths and weaknesses. My team and I are working to create useful links between different 3D printing processes. One very promising process is called cold spraying. The advantages of this technique are that it is very quick and can produce relatively large components. Its disadvantage is that it is not as precise as some other processes.

What object have you always wanted to print?

Krüger: The grand vision that motivates us is the possibility of printing a turbine blade. Turbine blades have to stand up to extreme levels of stress. If they could be printed, it would be possible to design much finer cooling channels inside the blades, and that would boost the blades’ efficiency. However, the blades also have to be very robust. If we could manage to combine these two tasks with the help of printers, we would be very proud of ourselves. Andreas Kleinschmidt

...the latest generation of machines uses multiple lasers, larger build chambers, automatic...
changing systems, and improved online monitor- ing features. Performance can be substantially increased as a result.”

Powers are also a major cost factor. “Some printing machine suppliers have used the same business model as the manufacturer of inkjet printers,” explains Langefeld. “This means that the companies supply not only the 3D printers but also the appropriate cartridges, which in this case contain specialized powder. However, the market analysis conducted for the Roland Berger study showed that experienced operators of several ma-

chines had already created their own supply sys-
tems, and this led to considerable cost savings.

In the study, Langefeld therefore came to the con-
clusion that the manufacturing costs of printed metalproducts will probably cut in half over the next five years and decline by another 30 per-
cent in the five years after that. This assumes, however, that the current average build rate will increase eightfold over the next ten years.

Heading for Faster Product Lifecycles. How-
ever, market researchers do not expect AM to re-
place conventional manufacturing processes. It will instead enable itself in niche sectors involv-
ing similar parts with minimal differences. Exam-
ple include precisely tailored teeth and dental crowns, hip joints, and skull implants.

Additive manufacturing also allows compa-
nies from all industries to design products in such a way that the products can do things that con-
vventional ones can’t. That’s why there is also a great potential in the use of new materials. For example, AM could conceivably be used for al-
loys, for precious metals, and for products in which different sections are “printed” with differ-
ent materials. Such products could include a ma-
terial that provides heat resistance and another for ensuring stability. Moreover, metals that melt at high temperatures could be used in completely new ways.

As a result, it would be possible to quickly pro-
duce exact and customized replacement parts on site when they are needed for individual machines or entire power plants. This would not only eli-
minate storage and transportation costs but also save money by preventing downtimes. For exam-
ple, the all-new method for making Siemens burn-

ter tips for gas turbines reduces the repair times for certain models by around 90 percent, because the replacement part no longer has to be welded together. Instead, the burner tip is simply printed onto the body of the burner, reducing re-
pair costs by around 50 percent.

Over the long term, this process will allow product lifecycle leverage, as analysts call it, to take effect. “This effect will set in sooner in the aviation industry than in the automotive sector,” says Langefeld. Put simply, a product made by means of additive manufacturing can last ten times as much as a conventional item it, for ex-
ample, it consistently reduces fuel demand by one percent during its entire service life. Accord-
ing to Langefeld, the challenge for the next three to five years will be to identify the products for which this equation is valid.

Sandra Zistl

Mission-Critical Software. Sierra Nevada Corporation’s (SNC) Space Systems, which is developing and building this reusable SUV, has gathered over 25 years of experience in space, supporting more than 420 missions and delivering 4,000 products, with no fail-
ures. More than 70 of these successful mis-
sions have been performed for NASA. In other words, it is a heavyweight with its ex-
pertise in the weightlessness of space. Every bit as stringent are the demands that SNC’s Space Systems makes of its partners. For the Dream Chaser mission, SNC has recruited a “Dream Team” of world-class companies in air and space travel, software, materials, and ad-
vanced research—including Siemens PLM Soft-
ware to develop and test it.

The Dream Chaser space taxi will bring people and supplies to the space station. SNC, which is building the Chaser, is using Siemens PLM Software to develop and test it.

Whether it’s space taxis or passenger cars, America’s Cup yachts or Formula 1 race cars, products are more complex, smarter and more connected than ever before. Product Lifecycle Management (PLM) software from Siemens helps manufacturers transform their operations into digital enterprises and lead the way - with smarter products and smarter machines making them.

Additive manufacturing will supplement conventional production methods, not replace them. AM offers advantages in the following areas of application.

Manufacturing End Products

Customized unique Items

Siemens uses AM to create new housing shells for small turbines which are individually adapted to the wearer’s auditory canal.

Very complex workpieces

AM can be used to produce very com-
plex workpieces, which would be al-
most impossible to create with previ-
ously available techniques. One exam-
ple of this is the all-new method for making Siemens burn-
nter tips for gas turbines, in which ventila-
tion ducts could be integrated for cooling.

Small batches

Produced cost-efficiently with AM.

Rapid Prototyping

Prototypes are increasingly being used during product development to test key properties before mass production begins.

The Future of Manufacturing

Facts and Forecasts

The Future of Manufacturing

From Virtual Space to Outer Space
Simulation software from Siemens plays a key role in developing, testing, and optimizing the production of complex systems in many sectors. Examples include the Dream Chaser space taxi (left), the Atlas V rocket, and the Mars Rover (below), as well as Maserati’s Gihibi sports car (p.73).

Siemens’ most innovative customers are already transforming their digital enterprises. What’s new is that these activities have moved beyond air and space travel to the manufacture of consumer goods.

Maserati, for instance, hopes to boost its position in the premium market with its new Gihibi and multiply its sales. Considering the expected associated growth in Maserati’s production volume, it is important to maintain the brand image and product quality associated with the manufacture of high-quality luxury automobiles. With this in mind, Gihibi’s end-to-end product lifecycle was entirely managed with Teamcenter as its collaboration platform and data backbone, NX for advanced design, and Tecnomatix for process definition and virtual simulation of production.

Showcase Factory. In order to bring such innovations to the table for its customers, Siemens runs its own digital enterprise: the Siemens Electronics Works Amberg (EW), along with its sister plant in Chengdu (SEWC), China. The two plants are an ideal example of how Siemens PLM software can be used. The manufacturing methods used in these plants reflect what could be standard ten years from now. For instance, products control their own manufacture. Simatic produces different controllers that will then optimize themselves on an individual basis. In Amberg, each product’s lifecycle can be traced down to the smallest detail. Every day, about 50,000 items of process information are generated and fed into the plant’s Simatic IT manufacturing execution system. The software defines all of the manufacturing rules and processes. In this way, the production process is recorded and controlled at a virtual level from start to finish. It is also closely networked with the R&D department. The latest data on the refinement of Simatic is sent directly to the manufacturing processes using the NX and Teamcenter software solutions.

“Siemens is the only company that makes such digitization possible throughout the entire product and production lifecycle,” Grindstaff says. “We take lessons from the Amberg experience and apply them toward helping our customers drive their own levels of innovation.”

Individualized Solutions. Optimum prepa- ration in the virtual space is everything. Thus, for example, leading U.S. machine tool manufac- turer Kapp Niles uses PLM software at a virtual level to make its machines ready for actual production. According to Kapp Niles, the Mechatronics Concept Designer – a program that creates and tests alternative mechatronic development concepts from an early stage in the development cycle – enables programming tasks to be completed at a work station in just a week, compared to three weeks of work on a machine’s real-world counterpart.

In the case of the Dream Chaser space- craft, one of the strengths of the NX software solution is that a wide range of designs can be simulated at little cost. Thus, the software makes it possible to determine, even before a prototype is built, which forms and combi- nations of materials would be most appropri- ate for the purposes of this SUV. For example, tiles are used to protect the spacecraft against high pressure and extreme tempera- tures when re-entering the Earth’s atmos- phere. While the Many protective tiles used on earlier Space Shuttles were of different sizes, making them costly to replace, more than half of the tiles on the Dream Chaser are of uniform size, thus substantially reducing manufacturing costs.

PLM software can also play a part in real- izing very individual wishes. An example is the world of sailing: the development of the perfect catamaran, with which Ben Ainslie Racing (BAR) would like to take the America’s Cup back to the UK for the first time since 1851. Using PLM, the team headed by Sir Ben Ainslie, winner of the 14th America’s Cup, can simulate a range of this to happen, all users must be engaged with the right information at the right time and in the right context to enable them to take decisions quickly and accurately.” Grindstaff considers this information an essential element in being able to draw up smart mod- els that will then optimize themselves on an ongoing basis. “The models have to know what requirements they must fulfill, and how to achieve that,” he says. “They have to un- derstand that they are part of a complex sys- tem and are linked together within it.”

In Formula One, there is no such thing as a finished product. A car is a continuously evolving prototype that experiences as many as 1,000 design changes every week, so im- proving engineering throughput can create a genuine advantage on the track. Four-time FIA Formula One Constructors’ World Cham- pions Infini Red Bull Racing relies on the dig- ital backbone provided by Siemens PLM to design new components, test them virtually, arrange their manufacture at the click of a mouse, and then install them in a car at des- tinations across the world.

Compared to the forces exerted on a For- mula 1 driver, a trip in the Dream Chaser should be positively gentle. Its special con- struction, worked out in virtual space, will make it possible to limit acceleration forces on occupants and sensitive goods at the crit- ical moment of re-entry into the Earth’s at- mosphere to just 1.5 g.

Inside the world’s fastest SUV, passengers will experience less than one-third of the forces they would be exposed to on a fast roller coaster ride – an amazing achievement when you consider that the journey began in a digital enterprise on the ground.

Sandra Zistl
Is machine intelligence opening the door to a new kind of industrial revolution? 

Mainzer: We are experiencing a fourth industrial revolution. The first was the steam engine, the second was Henry Ford’s assembly-line production, and the third was stationary industrial robots with electronic controls. Now the big step forward is that things and machines are starting to communicate. These “cyberphysical systems” are equipped with sensors, RFID chips, and software. As a result, a workpiece in a factory can communicate with a customer, the Internet and learning from experience.

Robots are developing rapidly. Their capabilities include communication with the Internet and learning from experience.

What’s your definition of an autonomous machine? 

Mainzer: They are machines that have degrees of freedom to make decisions. One example is a robot we have at the Technical University of Munich that has the assignment of setting a table for breakfast. Exactly how it must do that has not been predefined. It can freely choose how to accomplish this task, using probability calculations. In other words, it can decide whether to first get the cups out of a cabinet, the cutlery out of a drawer, or the marmalade from a shelf. This is in contrast to industrial robots, which can only carry out preprogrammed actions — they have no choice in the matter. The more degrees of freedom a machine has, the more autonomous it is.

Does this kind of behavior make autonomous machines intelligent? 

Mainzer: If you take the multifaceted intelligence of a human being as your yardstick, then machines fall short. But if you define intelligence as the ability to solve problems, then it applies to these robots. From this perspective, intelligence also seems to be measurable — in terms of the complexity of the problems that are solved. Many machines have a certain degree of intelligence; examples range from the expert systems that became popular in the late 1970s, to chess computers and self-driving vehicles. And if you object to this definition by saying that they don’t have a consciousness, you’re simply missing the fact that one doesn’t always need consciousness to perform tasks intelligently. Nature demonstrates that to us at every stage of evolution.

In your opinion, will increasing levels of machine autonomy affect employment and education? 

Mainzer: If you look at unemployment figures for Germany, a country with a high degree of automation, you can see that we have low unemployment compared with other European countries. But this doesn’t mean there are no challenges. For example, innovation cycles have greatly accelerated. As a result, for a long time now people have been preaching life-long learning, but I don’t see very much of that being implemented in the educational system. In the future, a large proportion of a company’s workforce will have to be involved in all the various stages of advanced training cycles in order to be able to adapt to the latest changes — and they will have to do this advanced training throughout their lives. Our schools are also still very oriented toward theoretical thinking. They certainly will need a stronger connection with technology and practice, as well as an awareness of the human challenges of a world that is strongly influenced by technology.

Interview conducted by Hubertus Breuer
The Plug-and-Play Car. Creating an overar-
ching software platform for cars is not easy. 
Today’s mid-range car has over 70 electronic 
control units for systems such as anti-lock 
braking (ABS) and automatic windshield 
wipers, as well as dozens of sensors that all 
have to work with one another. Then there are 
hundreds of sub-functions that run via these 
systems and share data. It’s very difficult and 
often costly to retrofit new functions into a car 
after it has left the factory, because techni-
cians have to install new cables and update the 
display systems and existing electronics. 

RACE, by contrast, is a computer archite-
cture that combines the strengths of the cen-
tralized and decentralized approaches to con-
trolling cars. The StreetScooter delivery van is 
the first step toward using this new approach 
in a mass-production automobile. Together 
with their colleagues from StreetScooter, 
RACE engineers first replaced the van’s stan-
dard control unit with a RACE control unit 
that regulates the drive system and the en-
ergy recovery process. The new software 
platform has not yet been completed, but it 
demonstrates that this technology can be in-
tegrated into vehicles equipped with a tradi-
tional system architecture. That’s why the 
electric StreetScooter has been named “Evo-
lution” by the project’s participants. 

The system’s development will not stop 
here. By 2016, engineers intend to reduce 
the number of electronic control units in the 
StreetScooter — and eventually in other ve-
hicles equipped with combustion engines or 
electric motors — and have the units’ tasks 
performed by only a few central computers 
equipped with redundant backups for safety’s 
sake. RACE’s standardized software platform 
enables engineers to upload functions — 
such as a new battery control system or an 
adaptation of a RACE control unit to the 
vehicle model in half.

We believe we can cut the 
development time for a new 
vehicle model in half.
In the near future, Wuhan’s police officers will be able to use a smartphone app to manually optimize traffic light timing.

I t’s the 8 a.m. rush hour in Wuhan. At the intersection of Luoyu Road and Zhongnan Road, cars are lined up for hundreds of meters. Hanhong Zhang, the traffic policeman who is responsible for this intersection, uses his walkie-talkie to call a colleague who is managing the next intersection over. After a brief discussion, Zhang reaches for the last resort: a gray box on the roadside, with a Siemens logo. Zhan opens a flap on the box and presses several buttons. The traffic signals for the cars turning out from Zhongnan Road suddenly turn red. The traffic jam on Luoyu Road shortens, but there’s still not a smooth flow of traffic by any means.

The traffic situation in Wuhan, China, can only be described as chaotic — and that’s not a good basis for automatic traffic management in a megacity. Together with municipal authorities, Siemens Corporate Technology came up with a brilliant idea: incorporating the police force into the system. The concept still has to overcome a number of obstacles. For one thing, even an induction loop doesn’t know where a traffic jam will end. That’s partly because drivers are constantly changing lanes — an activity that is almost a national sport in China. If the app is really to provide policemen with a better basis for making decisions about manual interventions, far more data will have to be fed into the system. Such data could come from cameras mounted on traffic light masts facing oncoming cars, or from radar speed monitors, or from magnetic sensors that are much cheaper and more robust than induction loops and send their signals via radio to controllers.

An App that Could Cut Gridlock

The traffic situation in Wuhan, China, can only be described as chaotic — and that’s not a good basis for automatic traffic management in a megacity. Together with municipal authorities, Siemens Corporate Technology came up with a brilliant idea: incorporating the police force into the system.

The traffic in Wuhan is nightmarish. In this city of ten million, it has increased dramatically in recent years. At the behest of the city, Siemens installed an Urban Traffic Control System in 2007. The system encompassed traffic controllers at more than 450 intersections — about two thirds of the city’s major traffic hubs. The controllers automatically switch the traffic lights on and off. By now it is obvious that this automatic system can no longer manage the traffic flow during rush hours, because it is based on the assumption that drivers will behave in a predictable way. However, that’s an illusion. When traffic jams keep lengthening and drivers have to wait longer than they like, even red lights are not an obstacle. In case of doubt, the boldest driver wins. At that point, Mr. Zhang has to intervene. He uses the buttons in the controller box to manage the traffic lights manually.

By integrating the knowledge of policemen, our system deals more flexibly with the uncertainties of traffic,” he says. Autonomic systems versus authority — that used to be a strictly either/or situation. If a policeman switches over to manual control, valuable information about the traffic situation is lost. That’s because Mr. Zhang can only see what’s happening at his intersection. He doesn’t have an overview of the traffic situation on access roads, which in some cases is measured by means of induction loops. The challenge now is to create a solution that combines the advantages of both systems.

Two years ago, Wei Qiu, a technical manager at Siemens Corporate Technology in China, decided to tackle this challenge. In a workshop structured according to the principles of Industrial Design Thinking, he worked with members of the police force and the city administration of Wuhan to identify the customer’s needs. That included the needs of the city’s police force, the traffic authority, and the urban planning bureau. Research activities included a survey of Wuhan’s police and taxi drivers. The result was a concept that is simple and yet revolutionary: equipping the traffic policemen who work at troublesome intersections with a smartphone app. The app serves as an information terminal that calculates traffic density on the basis of data from the Traffic Control System. In addition, during rush hours the app enables users to remotely operate the traffic lights manually. As a result, Mr. Zhang doesn’t have to stand on the roadside behind the controller box in order to direct traffic. Instead, he can supervise the intersection from a traffic island.

Turning Taxis into Congestion Sensors

Siemens set up an Innovation Center in a suburb of Wuhan in May 2013. The center is a branch of Siemens Corporate Technology that works closely with local authorities in order to develop an infrastructure for data services for future mobility management. At the center, several researchers are working on the implementation of the app concept. Yi Liu, one of the researchers, demonstrates on a tablet computer exactly what the app could look like. On a map of the intersection, red and green arrows show which cars have the right of way and which ones don’t — if all of the drivers obey the rules. It also shows the length of the line of cars waiting for a green light. This information comes from induction loops embedded in the asphalt and from Siemens controller boxes. But the most valuable data Siemens receives comes from the city’s traffic authority: information about the speed of almost all of the city’s 20,000 taxis. The taxis send their GPS position data via mobile radio to a platform run by the traffic authority, and Siemens then receives information about the average speeds of the taxis. That yields a good overview of the traffic flow throughout the city. Plans call for the app to be ready for use at the end of 2015.

At that point, the first group of policemen will be equipped with smartphones and the app. The concept still has to overcome a number of obstacles. For one thing, even an induction loop doesn’t know where a traffic jam will end. That’s partly because drivers are constantly changing lanes — an activity that is almost a national sport in China. If the app is really to provide policemen with a better basis for making decisions about manual interventions, far more data will have to be fed into the system. Such data could come from cameras mounted on traffic light masts facing oncoming cars, or from radar speed monitors, or from magnetic sensors that are much cheaper and more robust than induction loops and send their signals via radio to controllers.

Please Start Your Engine!

The Siemens concept is based on a “bottom-up” philosophy. Data from roadside controllers is processed with Siemens algorithms and then made available to policemen, the traffic authority, and the urban planning bureau by means of a Smart Data Service Gateway. These recipients then derive their own services from the data. One possible service would involve using the Gateway to send a message to the smartphones of waiting drivers to tell them to start their engines just before a traffic light turns green.

On the drive back from the Innovation Center, Technical Manager Qiu stops his car next to a traffic light controller that bears the name of a competing company. These controllers are cheaper than the ones from Siemens, but they aren’t networked; as a result, they’re not suitable for managing the traffic of the future. According to Qiu, the Smart Data Service Gateway expands the scope of competition by adding a data service dimension, and that gives Siemens an advantage. “By integrating the knowledge of policemen, our system deals more flexibly with the uncertainties of traffic,” he says. Authorities, it seems, where it makes sense to use them, plus authority where it’s needed — it could add up to a little less gridlock for many Wuhan motorists.

Bernd Müller
A 30-meter-long bolt of lightning sweeps through the hall and dissolves into a thousand images, while acrobats leap from breathtaking heights into a shimmering pool of water from which colorful fountains shoot into the air. Stages and galleries are transformed as if by magic.

The Han Show is a two-hour extravaganza of color, motion, and music. The spectacular theatrical event celebrated its premiere on December 20, 2014, in Wuhan, a city of 8.3 million inhabitants at the confluence of the Yangtze and Han rivers in central China. The show sets a new benchmark. “There were three top shows worldwide before 2014: O and Le Rêve in Las Vegas and The House of Dancing Water in Macao,” says Franco Dragone. “Now there is only one — the biggest of them all: the Han Show.”

On December 20, 2014, a spectacular theatrical event celebrated its premiere in Wuhan, China: the Han Show. The principal performers behind the scenes were huge robotic arms and sophisticated control technology from Siemens.

Secret Stars: Mobile Screens. Many aspects of the show deal with water, an element that is ubiquitous in Wuhan. In addition to a stage-filling pool and 80 performers, the show also features a group of secret stars: three gigantic LED screens that are as large as a wide as the entire stage. When the show begins, the audience quickly notices that the screens don’t just serve as a backdrop, but instead take on an active role in the story. Within seconds, the ten-meter-wide displays swerve upward to project images onto the ceiling or lie down behind the pool to create a visual extension of the water surface. There are seemingly no limits to these movements. The screens are sometimes arranged in a long line through which a bolt of lightning zaps into the water, while at other times they rotate like huge leaves in an imaginary storm.

Instead of huge hands, the screens are moved by three robotic arms — the largest ever used for a stage show. These arms are similar to the industrial robots used to weld metal sheets in the automotive sector, for example. The main difference is that the Han arms are much bigger, because each screen weighs 8 metric tons and this weight has to be moved up to 28 meters across the stage within seconds. Despite the weight the arms have to carry, they are almost as precise as their counterparts in factories. The steel arms’ transport paths must not deviate by more than two centimeters from the predeter- mined choreography or the screens would collide. To ensure such precision, the control system has to coordinate six joints, 12 motors, and 14 axes on each robot — for a total of 42 axes. “This is achieved by Siemens Motion Control,” says Renrong Hu, Chief Engineer of Stage Control Systems at Wanda Pictures of the Future Han Show Theater and produced the event. “Although we looked at various products, only Siemens offered a precise multi-axis control system that is easy to operate.”

New Stage for Siemens in China. This feat is accomplished by the SIMOTION D435 motion controller and the SINAMICS S120 drive system, which are widely used in industry. Although these systems are also found in stage technology in Europe and the U.S., they are new on stages in China. Siemens was competent enough and honored to take the breathtaking challenge at the Han Show, where the robots and the screens are unprecedentedly huge. “Although we never doubted that such a performance would be theoretically possible, we were somewhat concerned whether it would work in practice,” Dragone, who is an Italian theater director and a member of the Cirque du Soleil, knows this better than anyone else, because he himself designed the three shows, which he now plans to put on tour in Wuhan. In cooperation with the British star architect Mark Fisher (who passed away in 2013) and the costume designer Tim Yip, Dragone spent four years preparing a comprehensive work of art that merges the stage show with the surrounding space. Affectionately referred to as the “Red Lantern” by locals, the Han Show Theater has become another Wuhan landmark, next to the nearly 1,200-year-old Yellow Crane Tower. Illuminated by an interplay of reddish lights, the building, which was inspired by a paper lantern, is reflected in the waters of East Lake, the largest urban lake in the world. Theater has a long tradition in Wuhan, which is the birthplace of the Han opera, one of the key predecessors of the Peking opera.

Siemens Takes Backstage Pictures of the Future

The principal performers behind the scenes of the Han Show are huge robotic arms and sophisticated control technology from Siemens.
Precision systems guide eight-ton screens up to 28 meters in seconds.

Blocks of seats can move horizontally and vertically during a show to make way for a vast pool.

The ten meter-wide LED screens can glide into a new position in just seconds.