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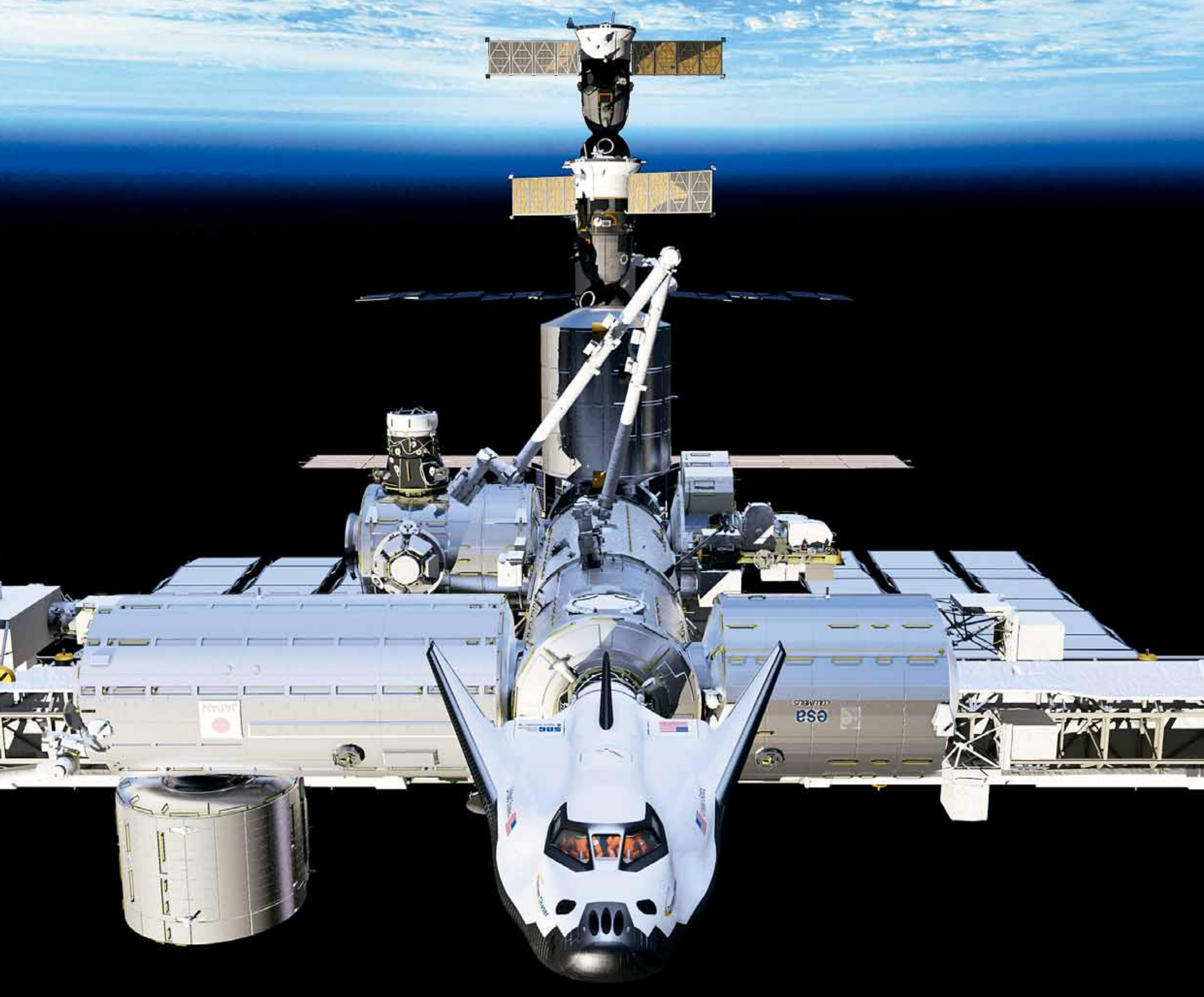
# Pictures of the Future

Best of | Spring 2015

The Magazine for Research and Innovation



## 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**

**Cover:** Sierra Nevada Corporation's Space Systems is developing and building the next generation *Dream Chaser* ® space taxi. Siemens is providing integrated product design, development and manufacturing software. For more, see p. 71.
Image: © Sierra Nevada Corporation





## The Future of Oil and Gas



## Tomorrow's Electrical Systems



## The Future of Manufacturing



## Features


# 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 term: 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.

# 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 Vectron all-purpose locomotive has radically changed the picture. This means that Siemens can produce frames, driver's 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.


# 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.

*Dive underground to the Gotthard Tunnel in PoF Digital's 360° feature: www.siemens.com/pof/gotthard*

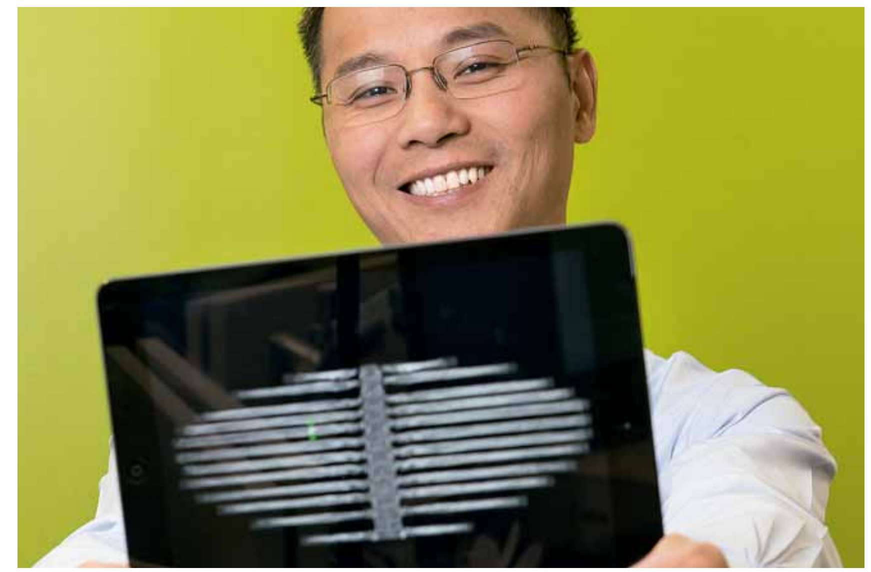


# Tomorrow's Data Transfers

**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.

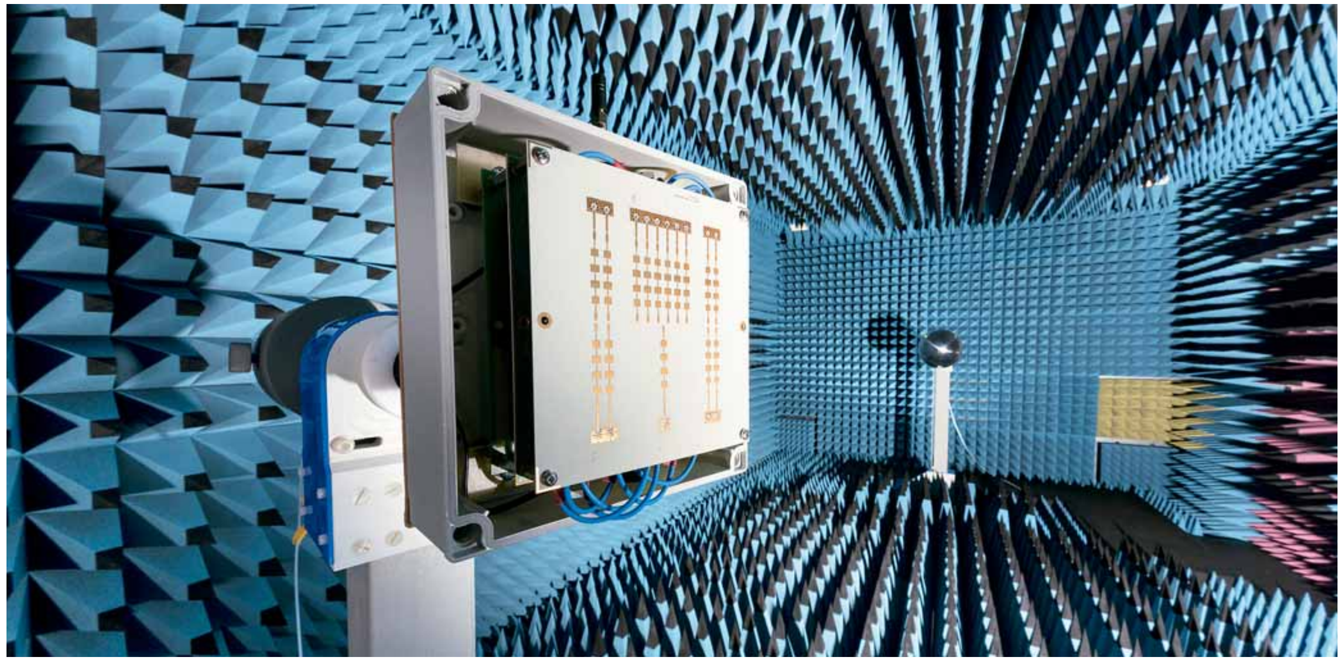
# New Software Identifies and Flattens Bones

**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.



# 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 $CO_2$ per kilometer will generate at least 630 grams of unnecessary $CO_2$ 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 a navigation device.

Sensors that document parking space use are actually not a new phenomenon. For example, a trial project in the Westminster district of London is testing the use of 3,000 ground sensors. The sensors, which are embedded in the road asphalt, simply register whether there is something above them — though not the size or position of the vehicle. But as soon as there is snow or dirt on the ground most of the sensors stop transmitting data. "That's how we got the idea of monitoring the streets from above," explains Dr. Florian Poprawa, the head of Hardware Development in the Advanced Parking Management research project.

**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. Radiation exposure 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.

**A System that Learns from Experience.** The sensors will transmit their data via mobile radio to software in a control center. There, the data will be processed and made user-friendly by calculating the real-time occupancy of parking spaces. In combination with location and destination data supplied by smartphones or navigation devices, vehicles will be directed to the nearest available parking spaces.

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.

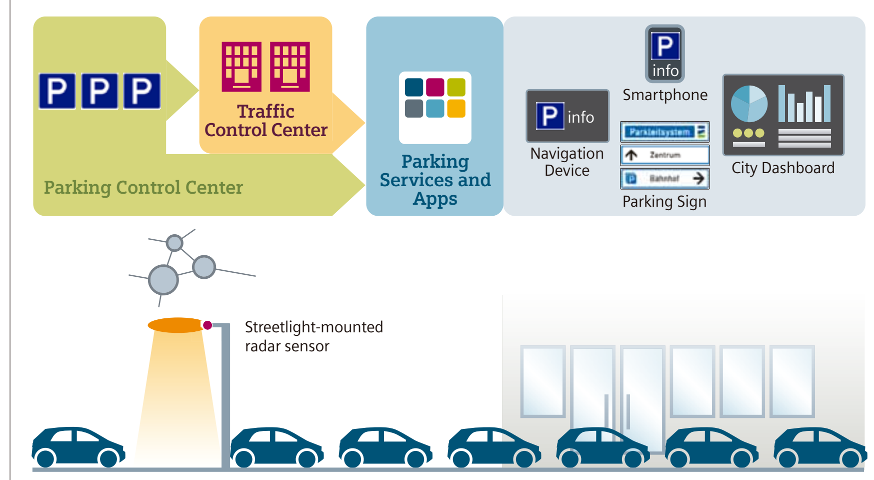
**Stress-Free Parking.** Advanced Parking Management could also help to make city parking less stressful and optimally distribute parking spaces. This would involve automatic pricing models that are adjusted to the time of day, the day of the week, and the length of time a car was parked. For example, 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.

But 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.

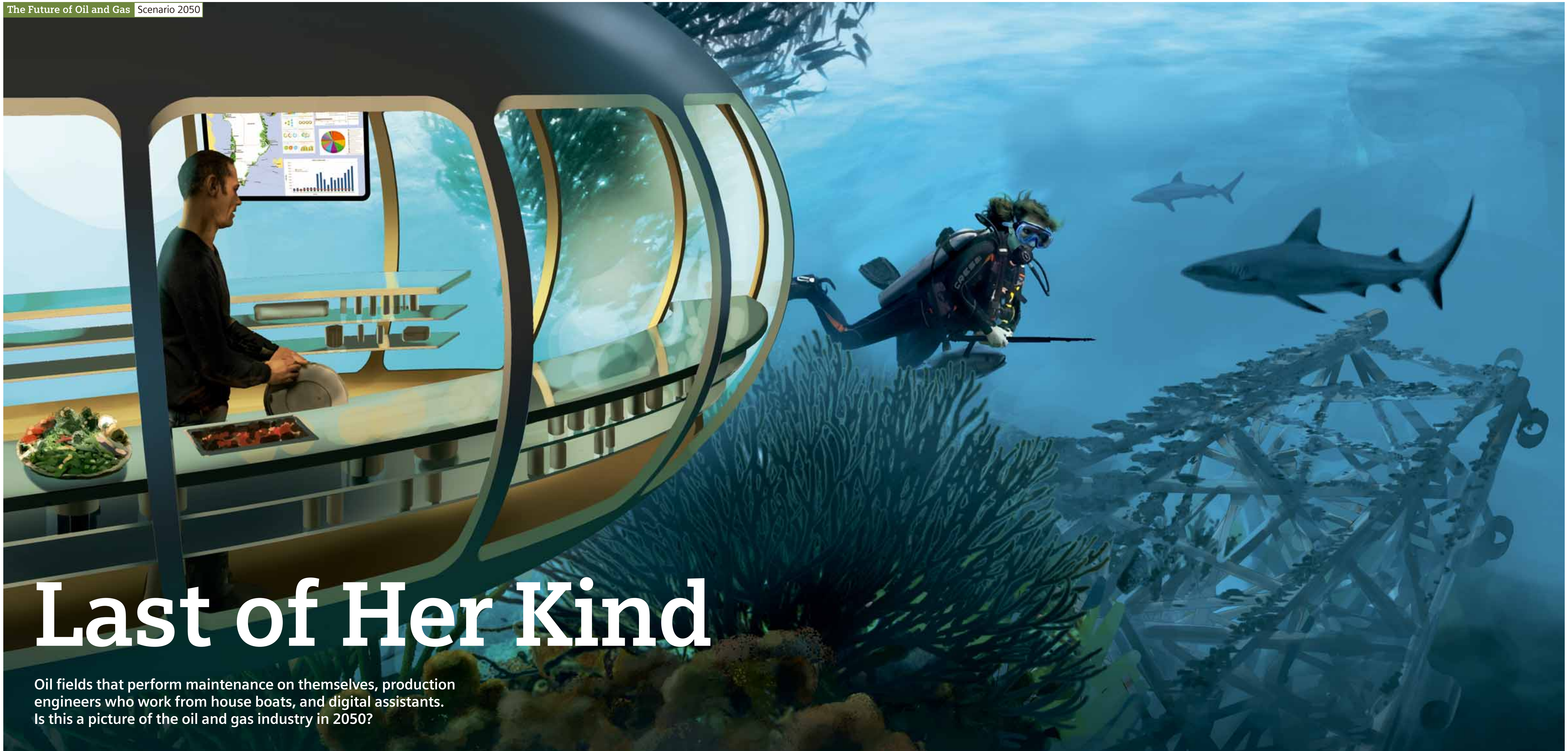
Such a system could help cities to efficiently locate illegally parked cars by means of software based on data from radar sensors. An additional feature could permit drivers to pay parking fees by means of an RFID code. In the future, this function could calculate parking fees automatically to the minute, 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 will switch to public transportation," 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*




**Radar sensors mounted in streetlights (bottom) monitor parking spaces and inform a control center when a space is free. From there, the information is transferred in real time to the smartphone or navigation system of the nearest driver who is looking for parking. Image page 6: Radar sensor testing.**

*For more on intelligent parking systems, see PoF Digital: www.siemens.com/pof/parking-sensors*



# Last of Her Kind

**Oil fields that perform maintenance on themselves, production engineers who work from house boats, and digital assistants. Is this a picture of the oil and gas industry in 2050?**

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 hologram room 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 exected. And somebody's ordering a lot of new

equipment on the automatic auction markets. 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 automated, her life has changed. There are hardly any more jobs now on offshore stations. Thanks to fast data connections, authorized production engineers like Vanessa can monitor the status of oil fields from anywhere in the world and intervene as 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 industry," 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 concentration and the development of creative solutions," 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 another and decide for themselves what they have to do to optimize production. This production volume, in turn, is determined by algorithms that are based in part on complex forecasts of supply and demand.

So it's true that only the really tough problems are left for Vanessa to tackle: crises, unforeseen breakdowns, and decisions on whether or not to keep entire oil fields in the network. Such a decision can earn millions for her employer — or cost millions.

"Vanessa, hello!" Geoff calls. "Wake up, sweetie. Production in an undersea oil field west of Greenland has been decreasing for the past hour. It's one of the older fields. For the past few months they've been pumping in $CO_2$ in order to force out the remaining oil. But now one of the compressors has broken down." A 3D image of the reservoir is projected onto Vanessa's goggles. "Look here," says Geoff as he turns the animated image, where a system lights up. "It has to be this compressor. It has turned itself off, for safety's sake. It's probably no longer watertight."

This would not be the first time such an incident has occurred. Twenty years ago, as the cost pressure on the oil industry was intensifying, Vanessa's employer wanted to save money wherever possible. He bought compressors for undersea oil fields from a relatively new supplier. The compressors were about 40 percent cheaper than the equipment offered by leading manufacturers. But now the company's previous thrift is proving to be costly. One component after another is breaking down — in some cases, 3,000 meters below sea level.

"We could take the field off the network until further notice, or we could immediately switch on a 3D printer in Greenland and produce a replacement part," Geoff suggests. He adds mischievously, "I can see that you don't know what to do next. But I can't make the decision for you."

Vanessa hesitates. The price of oil is dropping, so it might make sense to produce less oil for a while. On the other hand, the oil field paid for itself long ago and is operating cost-efficiently. "Let's repair it!" she finally says.

Geoff had estimated an 83 percent probability that Vanessa would make this decision. It's true that it will cost a lot to have the part printed and launch the drone that will bring it to the mobile repair ship, which in turn will send out a maintenance submarine to install the replacement part in the deep sea. However... "You're absolutely right, Vanessa. My calculations would also recommend that," Geoff says.

Suddenly Vanessa smells something burning. Oh no! "So long, Geoff," she murmurs, throws a kiss to the hologram, takes off her goggles, and opens the door. Alfredo is standing outside. "Sorry, sweetheart," he says. "I've burned up the fish."

"It doesn't matter," Vanessa calmly replies. "I'll get us another one." She starts to put on her diving equipment and takes another look at her twatch. On it she can see Geoff, who is winking at Vanessa and smiling. He's an assistant I could easily fall in love with, she thinks as she falls backwards into the water. Splash!

"It will take her at least 15 minutes to reach the reef and catch another fish," Alfredo thinks. He couldn't help noticing Vanessa's look at Geoff... And yet he had imagined things being so different. Only himself , Vanessa, and the boys on the houseboat — it could've been so beautiful. But now... he looks over at the ignition switch, considers how quickly the hybrid electric motor could whisk him to the mainland.

"I could leave her here," he whispers to himself. But then, looking down at the navigation system, sees Geoff's face staring at him with a devilish smile. "Not a chance," says the avatar. *Andreas Kleinschmidt*





## Warming up Ice Cold Gas

**A Siemens SGT-750 gas turbine** is being used in a novel way: to reheat 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 network. As a byproduct, the turbine also provides around 50,000 households with electrical power. This marks the first use of the SGT-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, improved 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 generates electricity, the remaining 60 percent consists of waste heat at a temperature of 459 degrees 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 its use of smart data, reduces maintenance-related downtime.

## Floating Power Plants for Japan

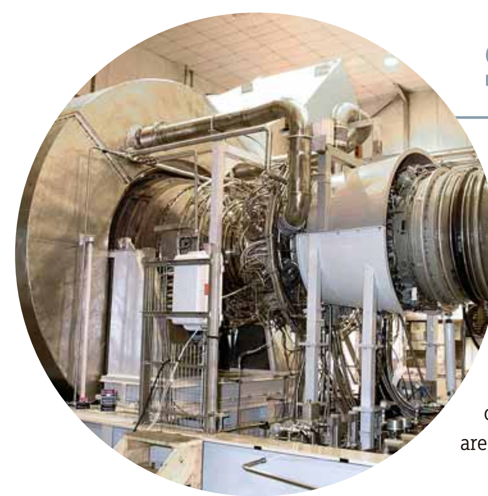
**Siemens** and the Norwegian company Sevan Marine are working on a concept for floating power plants. Anchored off the coast of Japan, such facilities could withstand earthquakes and tsunamis of the magnitude of those that affected the eastern coast of the country in March 2011. That disaster caused a meltdown at the Fukushima nuclear power plant, causing Japan to shut off its nuclear reactors. Since then the country has been able to satisfy its power needs only at substantially higher cost (see *Pictures of the Future*, Fall 2013). Floating power stations could use liquefied natural gas (LNG) and each could produce 700 megawatts (MW) of electricity for the mainland. Such installations would include a combined cycle power plant — a plant with both a gas and a steam turbine — as well as high-voltage transmission technology for transmitting electricity to the mainland.

*For more on floating power plants, visit PoF Digital: www.siemens.com/pof/japan*

## China's Coal Gets Greener

**Air quality is very bad in China.** However, it could be improved with the help of coal gasification — a technology in which Siemens specializes. In this process, powdered coal and water are gasified at high temperatures. The result is a synthesis gas of hydrogen and carbon monoxide. This gas is reacted with more water to create carbon dioxide and even more hydrogen. A coal gasification plant produces extremely pure hydrogen that can then be mixed with natural gas and turned into electricity. The $CO_2$ that is generated in the process is already separated so that it can be stored underground instead of being emitted into the atmosphere. Siemens engineers in Beijing are also working on the $CO_2$-free use of coal in combination with renewable sources of energy.

*For more on coal gasification technology, visit PoF Digital: www.siemens.com/pof/china*

## Sprinter among Gas Turbines

**Small, lightweight gas turbines** with high efficiencies are indispensable to the oil and gas business and to the growing field of distributed power generation. By acquiring Rolls-Royce's "aero-derivative" turbines unit, Siemens has rounded out its portfolio for gas turbines. Aero-derivative turbines are easy to transport, extremely sturdy, and capable of reaching full speed in next to no time. As their name implies, they are based on turbine engines for aircraft. They can be found operating on the high seas, in the middle of deserts, and in freezing cold regions. Originally, they were designed for use under the extreme conditions of flights at altitudes of over ten kilometers. Aero-derivative turbines have already been in service for many years on drilling platforms, storage and offloading facilities, along pipelines, and in LNG units, where they are used either as mechanical drives or for on-site power generation.

# Pumping Innovation in the Oil and Gas Industry

**Worldwide, total oil demand keeps growing. Low prices are fueling the trend. To remain competitive, companies need to reduce production costs. Siemens is supporting their efforts with innovations for the electrification, automation and digitalization of the complete production chain – from oil pump to gas pump.**

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 $CO_2$, 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-

coming more economical and could crowd out fossil fuels. (see page 28). According to British Petroleum (BP), four fifths of demand growth is currently attributed to emerging economies. But even their growing appetite for energy may subside at some point.

With less easy oil available and alternatives to oil becoming more viable, the way forward is clear: O&G companies need to reduce production costs. Some are leading the way by bringing more automation to oil fields and by using data in smarter ways. Simply put, in the future more valves will be opened and closed by machines than by people. And it will more often be machines that decide when to open or close valves, not humans. Flying workers to remote offshore locations in helicopters may one day be the exception rather than the rule.

**Big Data and Smart Data.** Automated equipment produces data – data that can be mined, aggregated into Big Data and transformed into Smart Data. Analyzing and understanding such production data helps to optimize processes. Here, visualization can be a key tool. Today, 3D visualization software makes it possible for users to immerse themselves in a virtual model of a facility. In-depth training sessions prepare technicians for future challenges. This is already saving customers real money.

For instance, the crew of an offshore platform in Africa was able to begin its training – virtually – while the facility was still under construction. Training sessions in the virtual model reduced the time needed to prepare workers for their tasks, thus helping to put the oil platform into operation more than two months earlier than planned. (see page 17)

Another area that offers opportunities to decrease costs is the replacement of mechanical drives with electrical drives. Today, a turbine often drives pumps and other machines directly, rather than a generator that then produces electricity. Powering equipment electrically instead, allows for energy savings – which in turn helps bring down production costs. So-called aeroderivative turbines can be particularly useful in this area.

So do we need to brace for years of low oil prices? No one knows. But there is one lesson the O&G industry has learned from history. While the price of oil can swing wildly, demand growth can remain surprisingly stable. Over the long term, we have seen price peaks above 140 USD and troughs below 20 USD; but yearly demand growth was between one and two percent over the long run. And more importantly, roughly five percent of existing capacity has to be replaced every year, because of depleting O&G fields. To make up for this, new fields need to be developed and the output of existing fields needs to be boosted, for example through injection of gas.

Automation and digitalization are expected to keep O&G competitive as a form of energy over the course of the next few decades. Whether we like it or not, every year mankind is likely to burn a bit more O&G than the year before. In terms of absolute numbers our demand is growing. In relative terms the importance of O&G may decline over time, as other sources of energy become more important.

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*

## Automation and digital technologies are expected to keep oil and gas competitive for decades.

Siemens technologies are making it possible to extract oil in extreme environments, such as the ocean floor (left) and offshore (right).

*For an interactive look at gas turbine production, visit PoF Digital's 360° feature at: www.siemens.com/pof/360gas*





# Technology Companies: Playing a Significant Role

**Dr. Omar Abdul-Hamid** is Director of the Research Division of the Organization of the Petroleum Exporting Countries (OPEC) in Vienna, Austria. Prior to this assignment, he was Manager of the Consulting Services Department in Saudi Aramco, the national oil company of Saudi Arabia. He holds a PhD in Materials Science & Engineering from Massachusetts Institute of Technology (MIT). He completed a program in Management Development at Harvard Business School and holds a bachelor's degree in Chemical Engineering from King Fahd University of Petroleum & Minerals, Saudi Arabia.


**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

## Siemens and other developers can take us to the next level technologically.

supplies is also expected to level out in the near future before declining. On an even longer term, and when considering other forms of unconventional supply, by 2020 we expect their total contributions to production to reach approximately 13 million barrels per day under the right conditions. However, America will both import and export oil at the same time and continue to use oil from the Middle East for the foreseeable future.

**The relatively low current price of oil is putting pressure on producers. What are companies doing to produce more cost-effectively?**
**Abdul-Hamid:** The industry is cyclical in nature. Changes in oil prices are not new and cost effectiveness will continue to be an important feature. Before the oil price tumbled in late 2014 and early 2015, it maintained high levels for a number of years. This may have bred some degree of complacency. It is healthy to step back to practices that help to control cost of capital and operation. In view of this, oil companies and investors will assess opportunities to plan and finance facilities that supply energy in response to growing future demand. Innovation is important for accomplishing this in a cost-effective manner. Using data in a smart way can help to improve exploration for oil and to optimize recovery. It can help at every step in the production chain. Automation will become more important in the oil industry, too.

**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 OPEC 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 ever 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

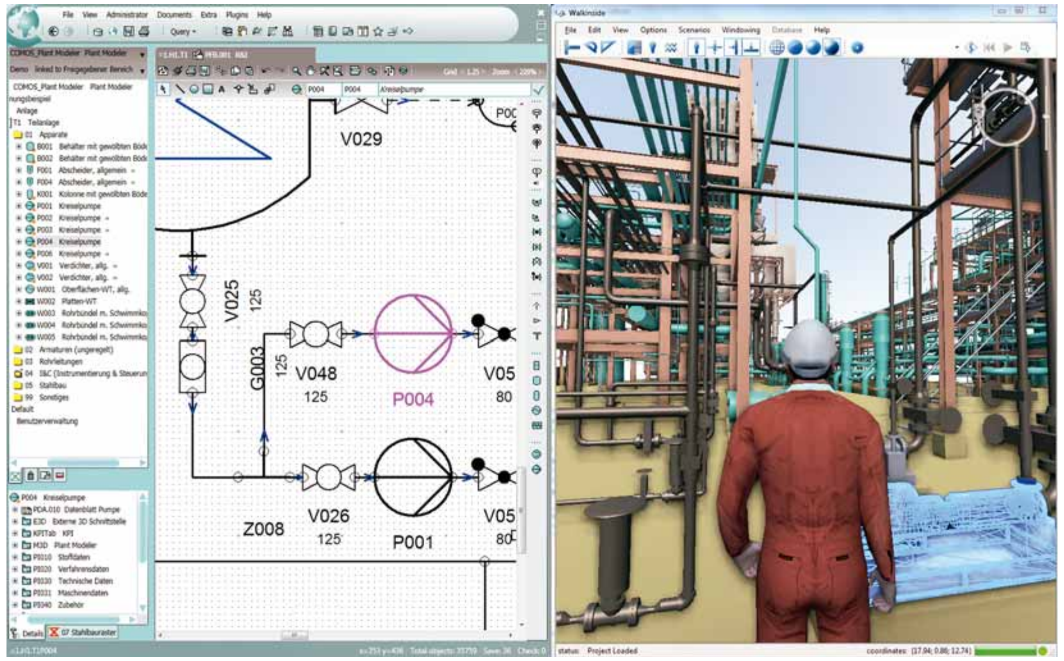
**Remote and technologically complex industrial facilities are characterized by high costs associated with plant design, maintenance, and workforce training. This is especially true for offshore oil and gas extraction. In view of this, Siemens has developed simulation software that generates precise, 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.**

It only takes two clicks for a maintenance technician at a leading global oil and gas company to "ship out," find himself standing in front of an oil rig's pump, and check the pump's condition. His first click is on the menu item "COMOS-3D-Viewing." His second click is on "Navigate" in a drop-down list. The pump now appears as a realistic three-dimensional depiction in COMOS Walkinside, which is a 3D virtual reality model-building system that can be used for immersive operator training.

And at this point, the technician sees himself depicted in the virtual model of the facility as an avatar — a virtual character — surrounded by thick yellow pipes and gray steel girders. Another click — this time on the pump — causes COMOS to display the pump's entire history. It displays the date on which the pump was installed, the number of hours it has since been in operation, and precise information regarding the times it has been serviced. Three small steps for COMOS and COMOS Walkinside, but a big step for the oil and gas industry.

**Why Paperwork is History.** Before the use of these innovative software solutions, such an inspection meant that a technician had to find the right document that contained his pump's last inspection report and further information out of thousands of papers and drawings. Only after he had finally found the report he was looking for could he begin with his actual task. He would have stepped out of the office into the stiff North Sea breeze, climbed up steel steps and ramps and past thick pipes, valves, and other equipment until he reached the pump he was looking for.

And all of this was done just to perform a routine inspection. Inspection dates were calculated on the basis of average empirical values regardless of how the environment actually affected the pump's performance and service life. Having completed his inspec-




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.

tion, the technician would have entered the new information by hand into a document and filed it. Not only was this kind of paperwork time consuming, but, in some cases, it was dangerous because of possible exposure to inflammable materials.

**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 every hour, counts." Larsen, who works for Siemens, supports GDF SUEZ E&P Norge, a customer that uses the COMOS and COMOS Walkinside software. "Not only do platform operators want to reduce downtime, they also want to use fewer people in such difficult working environments. What's more, such companies want their employees to be flown to platforms less often and minimize the amount of material that has to be transported back and forth."

**Maintenance in the Virtual World.** Perfect coordination is needed to achieve this goal. If production has to stop, it shouldn't do so because a single pump needs service. Ideally, it should be because several maintenance projects can be carried out simultaneously. That way, almost all of the major maintenance tasks are carried out on one of the platform's areas at the same time — system by system. Thanks COMOS Walkinside avatars, coordinated activities along these lines can not only be planned onshore, but also visualized and simulated there in advance without requiring employees to go to the platform in person at this stage. Instead, specialists go offshore online.

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 2,670 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 snow globe and look at it from the outside. COMOS Walkinside, however, allows me to look inside and even walk around in it. Moreover, it lets me link the content of the snow globe with smart data so that I can see the 'snow' falling and derive information on its consistency." The software enables users to experience the platform on their monitors. "If you can insert sunrises and sunsets, and also simulate the wind coming from any direction in addition – these are not romantic gimmicks,



## COMOS Walkinside helps users plan and simulate complex service projects.

but factors that strongly influence the facility's processes and have an effect on costs."

**From Drawers to Databases.** Instead of staring at technical drawings, users step right into the action. They enter the visualization by either clicking their way through a navigation tree, in which the facility's equipment is depicted by separate digital folders, or directly via relevant documents, such as piping and instrumentation diagrams in COMOS. Each folder contains the corresponding technical drawing that provides specialists with the key process they are looking for and its associated electrical engineering data and other information. All data is centrally stored for each object in COMOS. As a result, the combination of COMOS and COMOS Walkinside works like a huge virtual database that avatars can enter and that anyone can read, even if they don't have a degree in engineering. It links together all of the information (current and historical) regarding every piece of equipment and makes it visible both in COMOS Walkinside in a 3D environment and in the engineering data in COMOS. A drawer full of archived drawings is simply no match for such software, which represents nothing less than a cultural transformation.

Because 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*

# Research in Uncharted Waters

**At a unique lab in Trondheim, Norway, Siemens researchers are examining how power network components behave when subjected to extreme water pressures. In 2020, such a system will begin supplying energy to large oil and natural gas production sites at a depth of 3,000 meters.**

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 factories. Beginning in 2020, the Norwegian energy company Statoil plans to use such self-sufficient oil and gas extraction factories on the ocean floor.

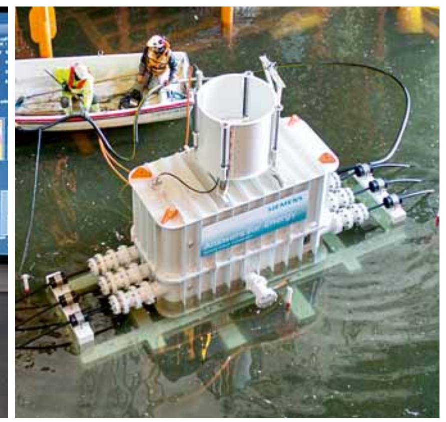
Siemens technology will supply the pumps and compressors with electricity. By then, individual network components will have to demonstrate that they can withstand the extreme conditions found at depths of at least 3,000 meters under the sea. This is a huge challenge, as researchers have had no experience 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 switchgears 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.

A soft hum can be heard in the "torture chamber" lab where cables and connectors are clearly arranged on the floor. The researchers have been able to use the brand-new Pressure Test Lab for about a year; previously the building housed an electric heating system factory. After donning protective goggles, Lystad walks slowly through the hall. Next to him is a series of 19 reinforced concrete chambers. Each of these small cells has a blue metal door. On each door hangs a laptop showing diagrams and rows of numbers on its display. One of the doors is open, revealing a silver cylinder in the middle of the cell. Several cables jut out of the ends of a tube that is about two meters long. "These are our pressure vessels," says Lystad as he knocks on one of the cylinders. "Each cylinder consists of 150 kilograms of solid metal. If we want to test a component, we put it in

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



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

the cylinder. We then fill the cylinder with oil and seal it shut. The pressure is raised to as high as 460 bar."

According to Lystad, the oil's purpose is to distribute the enormous pressure. "Before the grid component is actually lowered underwater, its entire housing is filled with oil," he says. "This allows us to make the system more compact than conventional air-filled containers. What's more, we won't need any complex cooling systems, since the oil dissipates heat." Lystad walks three steps to the other end of the chamber. "The cell surrounding the cylinder is open at the top and serves as a safety barrier. If anything goes wrong during the pressure tests, the energy will escape through the open top and the pieces will fly against the inside wall," he says.

Transistors, connectors, and other components are "tortured" for up to six months during continuous operation inside the tube. Engineers not only check to see if the components can withstand the high pressures and remain functional; they also want to determine if the parts wear out after 20 years of operation. To conduct such an endurance test, they equip the cylinder with a heating loop that keeps the temperature at a constant 95° C to simulate the aging process.

Once the Siemens experts are done torturing the components, they take the parts out of the pressure vessel and clean off the oil, which is then filtered and reused. "This is followed by a mechanical inspection," says 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. They have already completed their first deep-sea transformer and dipped the huge container into the sea, even though this "bath" was only a test conducted in Trondheim's harbor.

Lystad and his team have also assembled a 35-ton switching station. The giant stands next to the Pressure Test Lab in the hall, looking like a submarine in dry dock. A frequency converter, which ensures that oil pumps or gas compressors are supplied with the right operating voltage, is to be completed by the end of 2015. At that point the assembly will weigh around 120 tons. "We will then combine all three components into a single network for the final test," says Lystad. During 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." Continuity and progress also play a big role in Lystad's life beyond the Siemens research center in Bratsbergveien. He has a little farm on a small island near Trondheim. He often goes fishing there with his grandchildren — and thinks about his other passion: the dark depths of the sea.

*Florian Martini*

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





# An Expanding Appetite for LNG

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

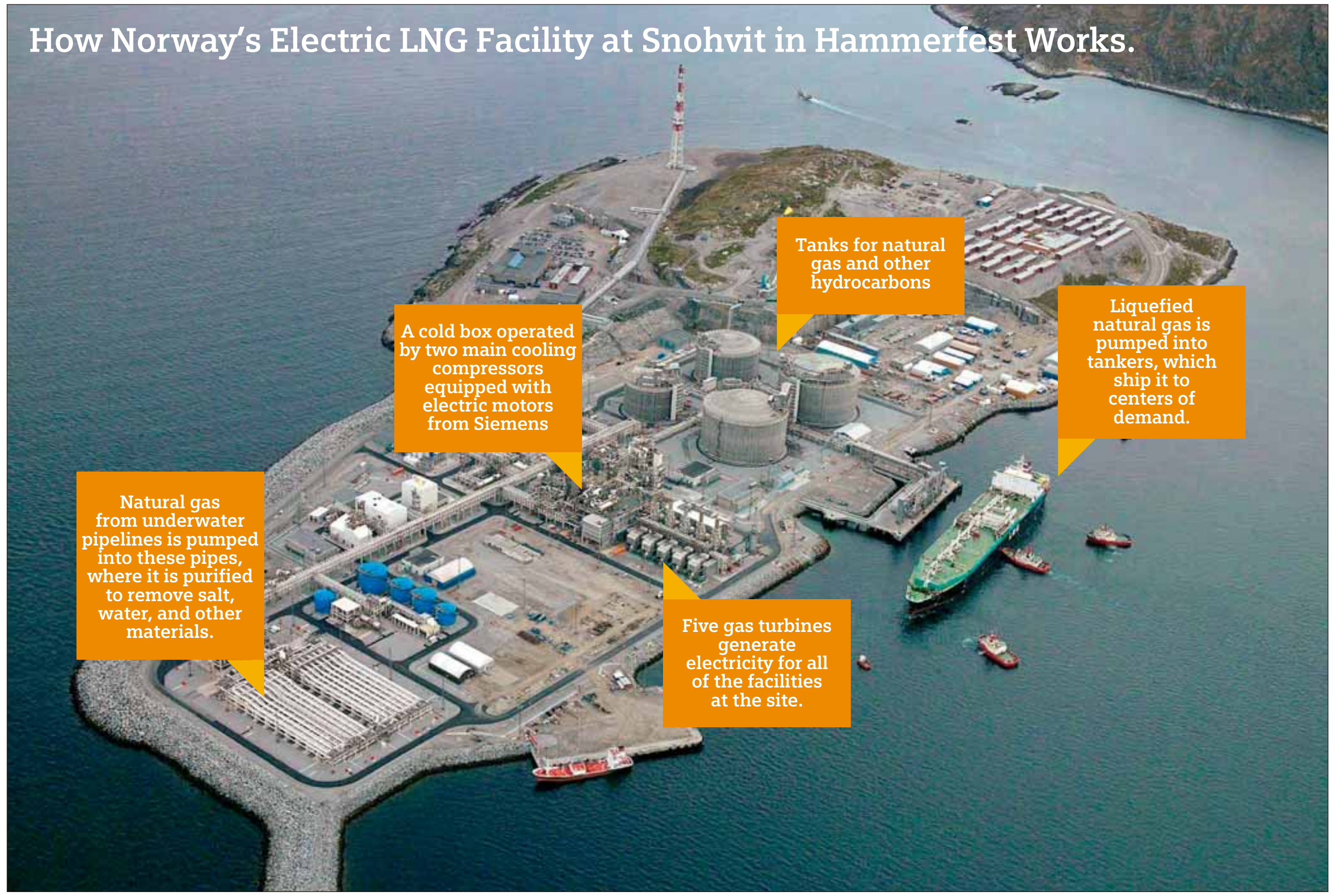
Few segments in the energy market are growing as rapidly as the production of liquefied natural gas. About a dozen new plants worth many billions of euros are being planned around the world. The International Energy Agency (IEA) predicts an annual growth rate for the LNG market of up to 40 percent. Siemens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

Clearly visible from afar, a slender, 40-meter-high industrial building towers into the sky. Inside is a huge cold box – a highly complex heat exchanger. Similar to an outsized refrigerator, it is the technological heart of a plant for producing liquefied natural gas (LNG). The tower contains a series of staggered cooling cycles that lower the temperature of the natural gas to minus 160 degrees Celsius, the point at which it becomes liquid. In the process, it is reduced to one six-hundredth of its normal volume and is thus much easier to transport.

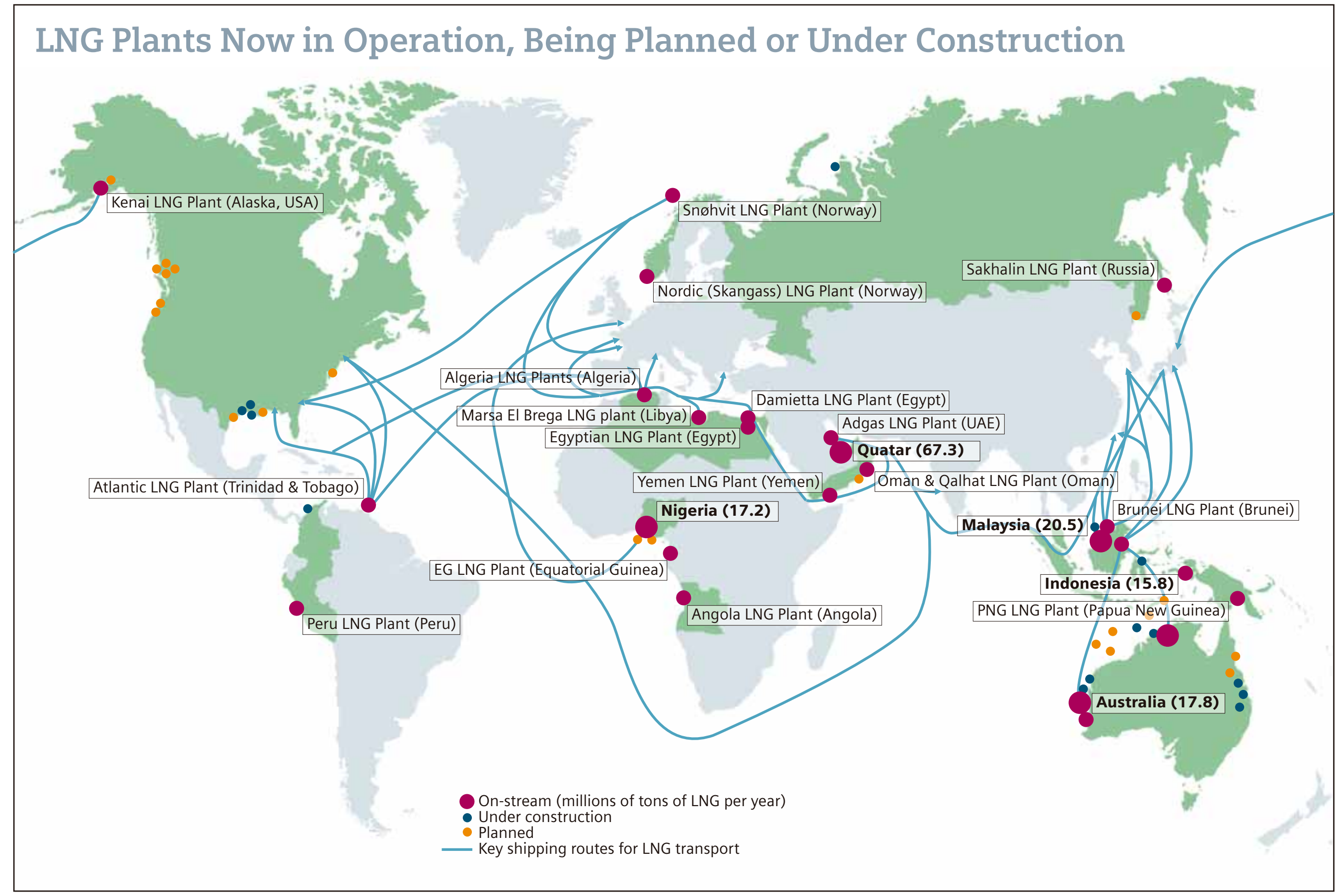
Other technical components — such as compressors, gas turbines, transformers, and sometimes, as in Soyo, Angola, an entire power plant — are grouped around the cold box. A mid-sized LNG plant takes up as much space as several football fields. But despite their size, only a few people have ever seen one of these industrial facilities. The great majority of LNG plants are located on a coast, usually far from any developed areas. Gas is delivered via pipelines, where it is liquefied and loaded onto ships.

**Price Tags in the Billions.** Planning a facility for liquefying natural gas requires taking the long view and being ready to invest a lot of money. "It takes about ten to 15 years from the first exploratory drilling to plant commissioning," explains Jörg Drüen, who is responsible for strategic projects in the sales department at Siemens' Power and Gas Compressors Division. LNG plant costs are huge. 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 grids.

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




Natural gas extracted from beneath the seafloor is transported by pipeline to Norway's Snohvit plant. In a first step, the gas is purified in a gas treatment facility at the bottom left (white pipes). From there it is pumped to the cold box, where it is liquefied. The associated compressors are operated by large electric motors from Siemens. Electricity for the compressors is produced by five gas turbines. The liquefied natural gas is first stored in the large tanks, from where it is pumped into ships. Ships carry the gas to centers of demand, where it is converted back into its gaseous state and fed into supply networks.




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 thus 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 Snovhit 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 have been built in Israel, Singapore, and Malaysia, reports the British business magazine *The Economist*.

In Europe, too, the construction of new import terminals is being considered. Operators of export facilities are therefore increasingly searching for ways to improve the efficiency of existing systems. One approach is to reduce energy demand. In the case of compressors, this is achieved by using special adjustable inlet guide valves (IGVs) to direct the gas flow at the blades in the best possible way, which increases efficiency.

Large liquified natural gas installations give rise to what is called "boil-off" gas. This results when LNG warms up, evaporates, and escapes from the tanks in spite of their insulation. As with compressors, the use of IGVs is worthwhile here too. "If the tanks are located at a great distance from the cold box, it can make sense to build a dedicated liquefaction plant for the boil-off gas, instead of transporting it back and forth and incurring more losses in the process," says Loscha. When the boil-off gas is reprocessed, there can be major fluctuations in LNG volume, depending on how much gas escapes from the tanks.

## Boil-off systems are essential to LNG facility efficiency, and Siemens has set the standard.

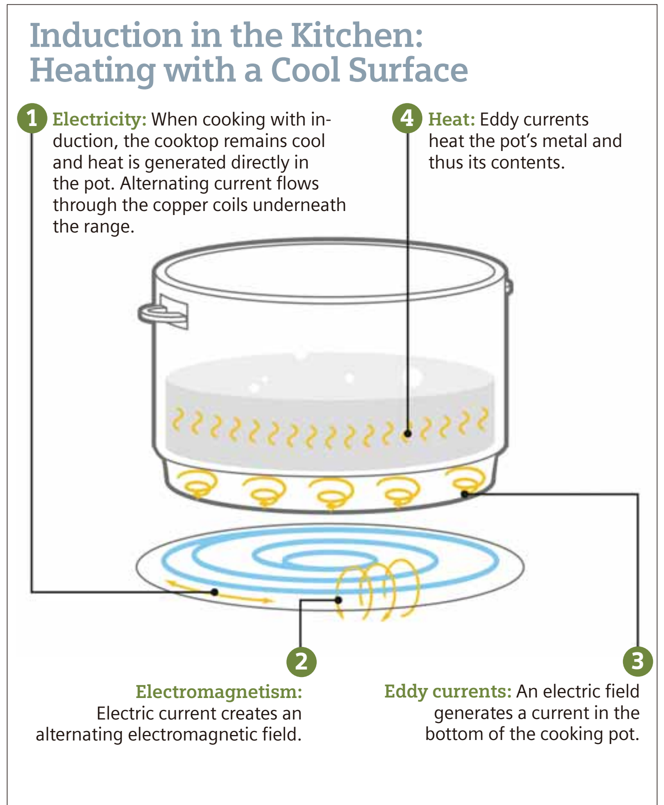
**Going for a FLNG?** "Compressor units for boil-off gas represent one of the greatest technological challenges in the LNG sector, because of the extremely cold gas involved," says Drüen. As early as 1972, Siemens developed boil-off gas compressors for an LNG system in Brunei, and the company has been optimizing the technology ever since. "Today, practically all boil-off gas systems are equipped with Siemens technology, so we've created an industry standard," says Drüen.

In recent years, LNG operators, i.e., global energy multinationals, have built very large installations with capacities of more than ten million metric tons per year. But today there is an increasing tendency to favor mid-sized facilities. "Several very large installations ran way over budget," says Drüen. It was recognized that it is more economical to set up a succession of multiple compressor trains with lower capacities on a given site. "Siemens is currently participating in the construction of approximately a dozen systems, primarily in Australia, Indonesia, and Malaysia," says Drüen.

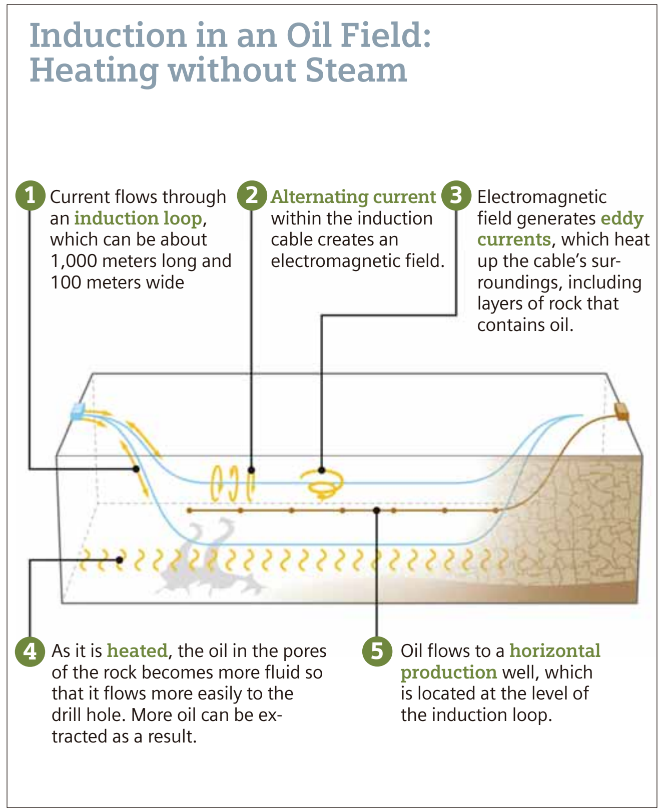
Another trend in the LNG market is floating LNG installations, otherwise known as "FLNGs." Such facilities are used to liquefy the natural gas extracted from below the sea bed. In these cases, operators can do without expensive undersea pipelines. The largest floating offshore installation is Prelude, 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*

*More LNG graphics regarding facilities and markets at: www.siemens.com/pof/lng*




Induction cooking uses alternating current to generate an electromagnetic field that in turn heats a pot.




Induction "cooking" in an oil field heats deep layers of earth, thus reducing the viscosity of trapped oil deposits.

# Fresh Recipes for Extracting Oil

**Lower $CO_2$ 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 producer Wintershall. The technique is similar in many ways to the process that occurs on household stove tops every day. "It works like an induction cooking range," says Andreas Koch, Project Manager for EM Heating at Siemens.

More specifically, an inverter feeds alternating voltage with a frequency of 10–200 kilohertz into an induction cable that runs in a long loop deep below the surface and directly into an oil reservoir. The reservoir needs to have a certain amount of conductivity — which is where the level of moisture in the sourroundig ground comes in.

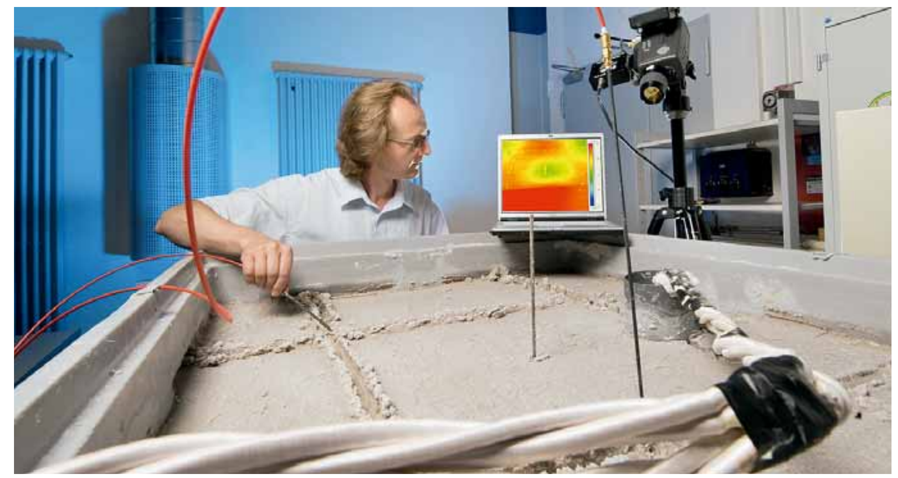
An electromagnetic field is generated in the area around the induction cable through the application of alternating current in much the same way that such a field is created in the cook top of an induction range. Such fields produce eddy currents whose ohmic losses directly heat up an oil reservoir.

The oil becomes less viscous and flows to a production well located underneath the induction loop. In a household induction range, the cooking pot rather than the induction coil is heated. As with induction ranges, an inductor in an oil reservoir also stays "cold"; only the surrounding area heats up. This heat is localized and thus not noticeable on the surface.

The procedure was initially tested by Siemens Corporate Technology (CT) in a sandbox. CT researcher Bernd Wacker demonstrated that moist sand can be heated through electromagnetic induction alone. The current installation under a meadow near Deggendorf represents the first phase of a series of tests — literally a "field trial." Here, a 200-meter induction loop runs at a depth of 15 meters below the meadow.

**Experts expect that more than three trillion barrels of heavy oil can be exploited worldwide.**

Siemens and Wintershall Holding GmbH, the biggest German internationally operating oil and gas producer, have formed a research partnership in order to jointly test the induction technique as an oil-extraction application and, if successful, develop the system to a market-ready stage. "The induction method definitely offers great potential for the future," says Wintershall Project Manager Erich Leßner. Indeed, experts to date have proved the existence of reservoirs containing more than three trillion barrels of heavy oil around the world. "Most of these can be exploited using induction technology," says Leßner.



Siemens Corporate Technology researcher Bernd Wacker originally tested and proved the concept that electromagnetic induction can heat sand if the sand is moist.

**Diving Deeper.** According to Koch, one of the major challenges over the next few years will involve developing affordable methods for drilling roughly 1,000-meter long horizontal loops into the ground and then inserting installation pipes made of a special plastic to carry associated induction cables.

One possible method of doing this is the so-called river crossing drilling technique, which is used to create a bore that runs as if it were a tunnel underneath a river. The bore is drilled into the ground at an angle of 20–30 degrees until it reaches the desired depth. After that, it continues horizontally and then back upwards at a designated spot where a turning point for the loop has been defined.

"We still can't drill at right angles, so to speak," Koch explains. In other words, the inductor cable rises back above the surface and is then fed back in the other direction and "under the river" again.

When viewed in cross section, the bore path looks similar to a canoe. Drilling depths of up to 400 meters have been achieved to date. However, the induction method can also be used at depths in excess of 1,000 meters.

**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 Will Be a Key Part of the Energy Picture

**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 despite the renewables boom, fossil resources continue to play a crucial role. According to the *2014 BP Statistical Review of World Energy*, worldwide consumption of fossil resources rose by 2.3 percent in 2013. In 2012, by comparison, the increase was only 1.8 percent.

Four fifths of that worldwide increase occurred in emerging economies. The BP report indicates that oil, which accounts for almost one third of world energy consumption, remained the most commonly used fossil resource. At the same time, however, "black gold" lost market share in 2013, as it had in previous years as well. Its share of the energy mix hadn't been that low since 1965.

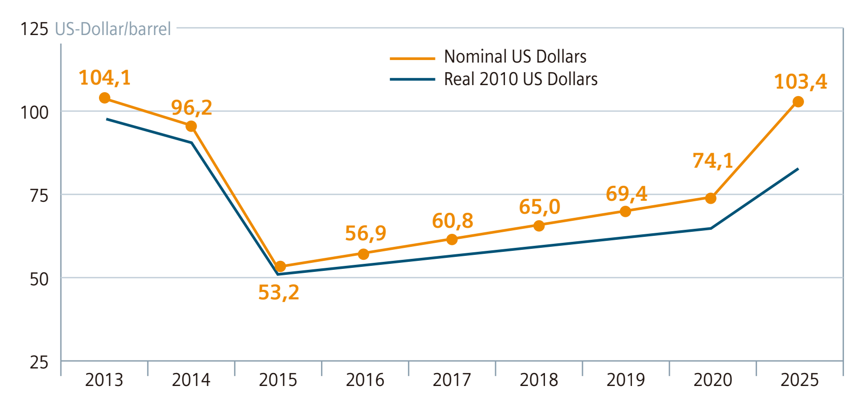
At the same time, there was a sharp drop in prices: while a barrel of oil cost over US$110 in June 2014, it was just over $50 in spring 2015. The reasons for this are complex. Among other things, a flagging global economy is leading to reduced demand for oil. At the same time, the United States, historically a major oil importer, has drastically reduced imports because of its own booming oil production; and Saudi Arabia, as the world's largest oil 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 percent 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 by 2040. Global demand for natural gas in particular will grow by more than 50 percent, according to the report. That is the highest growth rate of all fossil fuels. By 2030, according to IEA calculations, natural gas will become the leading fossil fuel in OECD states too. The share of coal, on the other hand, is predicted to fall to 27 percent by 2035, when it will be level with natural gas.

Unconventional natural gas will be responsible for almost 60 percent of worldwide growth. An analysis undertaken by Siemens' Corporate Information Research Center (IRC) identifies shale gas as the fastest growing segment. In the U.S., for example, it already accounts for 44 percent of total natural gas production. In the U.S., energy is plentiful and less expensive than in other countries, due in no small part to fracking technology. IEA experts expect that in the 2020s the average cost of an energy unit will actually be lower in the U.S. than in China.

**Hooked on Gas?** According to the latest figures from the German Institute for Economic Research (Deutsches Institut für Wirtschaft, or DIW), the EU meets almost a fourth of its natural gas needs with imports from Russia. To reduce dependence on imports, the DIW recommends using existing infrastructure more efficiently and expanding the pipeline system and import capacities for liquefied natural gas (LNG), which can also be imported by ship. At 184 billion cubic meters, the EU's total LNG import capacity in 2013 amounted to almost 40 percent of its natural gas consumption. Additional facilities with a capacity of over 30 billion cubic meters are under construction.

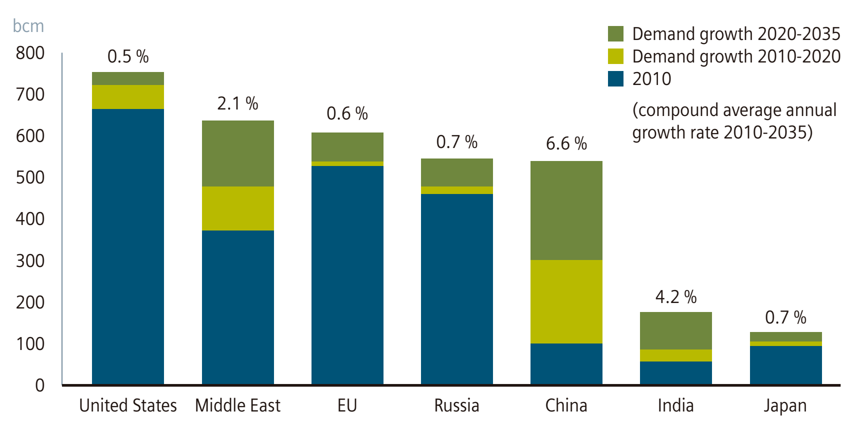
## Expected Development of Petroleum Prices




The World Bank predicts that the price of oil will bottom out at somewhat over US$50 per barrel in 2015. It is not expected to reach 2013 levels again until about 2025.

Source: World Bank Commodity Forecast Price data, January 2015

## Where Natural Gas Is Expected to Be Consumed...




Demand for 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.

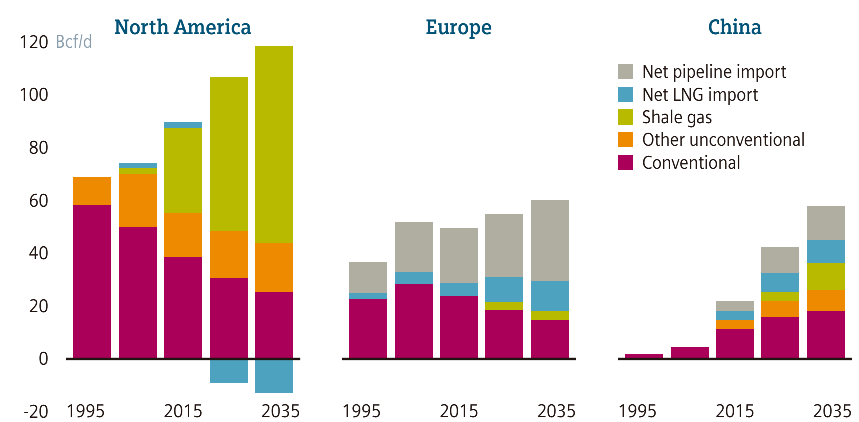
The situation in the U.S. is very different. According to the U.S. government's Energy Information Administration (EIA), the country could become a net exporter of natural gas starting in 2016. The greatest challenge in this regard is the lack of infrastructure needed to further refine and transport the raw material — and thus to export it.

"There are over a dozen projects in the U.S. for exporting liquefied natural gas. The first LNG terminal is expected to enter service in 2016/17," says Roberto Cominotto, manager of the JB Energy Transition Fund.

**Fossil Fuel Subsidies: Bad for Renewables and Efficient Technologies.** The IEA has criticized subsidies for fossil energy carriers, which amounted to $550 billion globally in 2013, more than four times the amount of subsidies for renewable energies. According to the IEA, this hampers investments in renewable energies, oil reserves that are difficult to exploit, extensive gas logistics systems, and new coal-fired power plants with $CO_2$ capture. If current policies continue, the IEA estimates that $CO_2$ emissions could rise by 20 percent between 2011 and 2035, making them twice as high in 2035 as they were in 1990. This would cause average global warming of 3.6 degrees Celsius by 2100, instead of the target level of 2 degrees. According to calculations of the Intergovernmental Panel on Climate Change, the world can only release an additional 870 to 1240 metric gigatons of carbon dioxide between now and 2050. Only then, it says, will there be a real chance of limiting warming to 2 degrees. According to an analysis carried out by researchers Christophe McGlade and Paul Ekins of University College London, that means that 30 percent of all oil reserves, 50 percent of all gas reserves, and as much as 80 percent of all coal reserves would have to remain in the ground, unused.

**Huge Growth in Renewables.** The IEA predicts that renewable energies will account for almost one fifth of global energy consumption by 2040. In 2012, that figure was only about 13 percent. The share of wind and photovoltaics in the global energy mix is expected to quadruple. The highest global growth rates are for wind power (34%), hydropower (30%) and solar energy (18%). In the European Union, for example, wind power is expected to rise to about 20 percent of total power generation by 2040. *Sylvia Trage*

## Shale Gas: A Boom that's Limited to North America

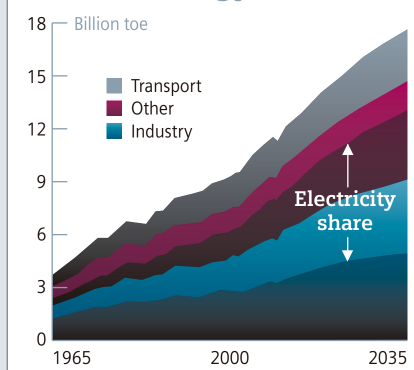



While the importance of shale gas is expected to grow considerably in North America over the next two decades, it is expected to have little significance in Europe and China.

*Bcf/d = Billion Cubic Feet per Day

Source: BP 2014

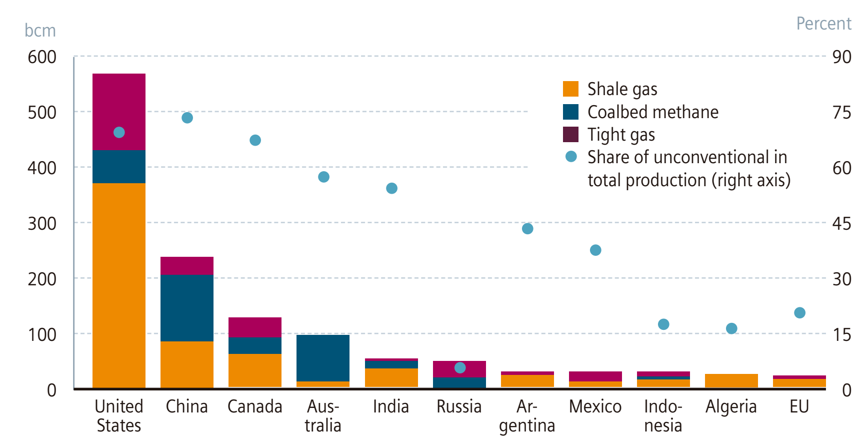
## Sector Energy Demand




Growth in energy demand is being driven mainly by industry, which will be responsible for over 50 percent of the increase between 2012 and 2035.

Source: BP 2014

## ... And Where it Is Expected to Be Produced.




By a wide margin, the world's largest producer of unconventional gas in 2035 is expected to be the U.S.

Source: IEA WEO 2012; E ST MC

# 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 monotonous 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 and offloading vessel." The 300-meter-long facility is located 57 kilometers south of Port Harcourt on the open sea and is linked to the surrounding oil fields by pipelines on the ocean floor. Everything that is pumped up in the oilfields lands in the giant belly of Unity, which can hoard up to 2.2 million barrels of oil — almost 350 million liters. Tankers dock to Unity two to three times a month to pump out a shipment of oil to bring to customers all over the world.

The helicopter pilot now turns to the left and flies around Unity in a wide curve before finally getting ready to land. The oil production platforms that extract oil from the rock beneath the ocean floor can be seen on the horizon. The water here is 62 meters deep. From a distance, the platforms look like giant insects that have landed on the water. They have many extensions and bridges, complex metal frames that stabilize the structures, and towers and smokestacks.

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 workday 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.

Whenever 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 Geregu 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

**Left page top: The FSO Unity floating oil 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).**

## Three identical on-board turbines ensure uninterrupted operations on the FSO Unity.

Hopes for a better life have been realized for Waheed Raji and his family (left). The family lives in Rukpokwu Town, a suburb of Port Harcourt. Thanks to his job, Raji has been able to build a large house. But he is still dissatisfied with the state of Nigeria's infrastructures, particularly its roads (above).

for 95 percent of the country's exports. However, crude oil is often exported, processed abroad into gasoline, and then re-imported. Diesel generators pick up the slack during blackouts, and 60 percent of all Nigerians simply have no access to the power grid.

Where there is little, a lot is needed. That's why the buildup of Nigeria's infrastructure presents a huge opportunity — not just for 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. Recently he was able to take his wife on the Islamic pilgrimage to Mecca, the Hajj.

The attractive extra pay for workers on offshore oil and gas industry platforms is meant to compensate for deprivations big and small — being far from their families, working long shifts, and in many cases, including Raji's, having to share a cabin with 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 barbed 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 ocean 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."

Modele Idiahi moved from London to Lagos.

Electricity is bringing hope to Nigerians.

FSO Unity holds almost 2.2 M. barrels of oil.



## 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. If something goes wrong because of a maintenance error, in the worst case production at connected oilfields could suffer. That's why maintenance services in the oil and gas industry are well paid.

Siemens technology is also used 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 when they go to bed. Raji often thinks about his family at these times. "I think about our house, my wife and, most of all, my children," he says. "The fact that I'm able to pay for their education is more important than anything I could ever buy for them." It costs Raji around 300,000 naira (€1,400) per year for the private school attended by his oldest child, ten-year-old Rahamatalah.

The Rajis built their house in Rukpokwu Town, a suburb in the northern part of Port Harcourt. The main street is a colorful jumble. Under banana trees, laundry hangs to dry, plastic chairs stand outside small huts, children offer to polish the shoes of passersby, and goats and chickens browse among the garbage on the edges of the muddy street, which is dotted with potholes. Makeshift shops in wooden sheds and stands offer all kinds of household goods, such as tiny packages of soap for twenty naira, approximately nine euro cents.

An increasing number of solidly constructed homes made of concrete have been built in the area during the past few years — and the Raji family's house is one of them. Raji's wife, Rukayat, takes care of the children and also runs a cement shop. She would like to get into the wholesale business in a few years, when she has the required start-up capital and the children are a little older. "So far, things have gotten better for us every year, and I firmly believe this will continue," Rukayat says.

She's not alone in her optimism; a majority of Africans would agree with her. Nonetheless, Rukayat also knows that Nigeria still has to overcome tremendous challenges. "The country needs to broadly expand its infrastructure," she says. "We need roads, clean water, and electricity. But more than anything else, we need better education." Rukayat's two oldest daughters want to become doctors "in order to cure malaria," as the girls say. Their brother also knows what he wants to be: "an engineer, like my father."

An entire country is dreaming along with Raji's children. The dream is one of greater opportunity, less corruption, affordable education, safe streets, and cities worth living in. In order to achieve such development, Nigeria will need to end its long-term dependence on oil. That's why some people view the current decline in oil prices as a warning. At the same time, however, the income the country is generating from oil allows it to invest in infrastructure and establish new industries. In other words, Nigeria needs oil in order to overcome its dependence on it.

Nigeria's Minister of Power, Prof. Chinedu Nebo, says, "We need more Waheed Rajis — we need thousands of them. In 50 years, Nigeria will be one of the most important economic powers in the world, and our children will want to live here rather than emigrate." That's the Nigerian dream. The question is: Will it come true or will it burst like a soap bubble? By the time 2065 rolls around, Raji's children may be able to tell their own grandchildren how it all worked out.

Waheed Raji's workday has ended. He adjusts his helmet and looks up at the sky as rain patters down on his face. There's been some bad news. His return trip by helicopter has been delayed and Raji will have to spend the night on the FSO Unity, contrary to his plans. "More time with the turbines, less time with family," he says. He'll spend some of the time going through the maintenance plans in his cabin.

Evening slowly settles over the Gulf of Guinea. Raji looks out of the small window of the cabin and sees that it's stopped raining. The gas flames on the oil platforms glow in the distance like magical torches that light up the sea.

*Andreas Kleinschmidt*

In Lagos, cell phones are everywhere.

*Video report: Facilitating offshore energy in Nigeria.*
*www.siemens.com/pof/nigeria*

# 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 it 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 will slip in the marked area. And that's precisely what happened at the time the system had predicted. In this case, researchers calmly watched as tiny cracks gradually expanded until the predetermined breaking point was reached. They had even provoked the break by causing the water to put the test levee under pressure from several sides at once. In reality they would have been able to determine, weeks or even months in advance, exactly where the situation could become critical and what parts of the levee would have to be reinforced or reconstructed.

Ever since the first levees were built, people have wanted to be able to predict when the bulwarks that protect them and their infrastructures might break. This ability is becoming increasingly urgent. More than two thirds of the cities in Europe already have to regularly take measures to protect their inhabitants and industry against floods — not only at seacoasts, but also along overflowing rivers. The more frequently climate change causes extreme weather conditions, the more urgent this problem will become.

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.

"I sometimes wonder why we Dutch people used to build all of our important structures below sea level," jokes Peter Jansen, who heads a department at Waternet Amsterdam, Siemens' levee monitoring system's pilot customer. Waternet is responsible for over 1,000 kilometers of levees in the greater Amsterdam area. The levees protect 700 square kilometers of land on which more than one million people live. In addition to ensuring the supply of drinking water and handling wastewater, Waternet provides flood protection on behalf of the local water control board. Although levee monitoring is one of the organization's standard tasks, it has never been as precise as it is today.

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


**Bernhard Lang (left) directed the development of a levee monitoring system that was recently installed at a pilot customer in Amsterdam.**

**Real-Time Data at One-Minute Intervals.** "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

sensors are connected to communication units equipped with SIM cards. The units use the GPRS mobile radio service to transmit the data to a control center in Karlsruhe, Germany. The center converts the initially unspectacular measurement results from raw data into smart data that can be sent to any mobile device.

If the system measures a temperature of 14 degrees Celsius within the levee, this could mean that something is wrong, because groundwater has a temperature of around 8 degrees Celsius, and that should also be the temperature inside the levee. The higher temperature would mean that warmer water has seeped in from outside. But before the system sounds an alarm, it first compares the real-time data with pre-trained knowledge such as the depth of the groundwater, the amount of precipitation that normally falls in the affected area at that time of year, and whether there was a drought in the area recently that would have allowed the levee to take up more water.

"The levee is like a living organism," explains Lang. "It expands and contracts. The fact that water is seeping into the levee doesn't necessarily mean that there is any danger." That's why researchers also need to know what the levee is made of at the affected area, because it enables them to determine its "slope stability factor." Various factors are involved. But thanks to the use of the latest sensor data, a learning system's continuously collected long-term data, and mathematical models, these factors are combined into a fascinating, unified whole.

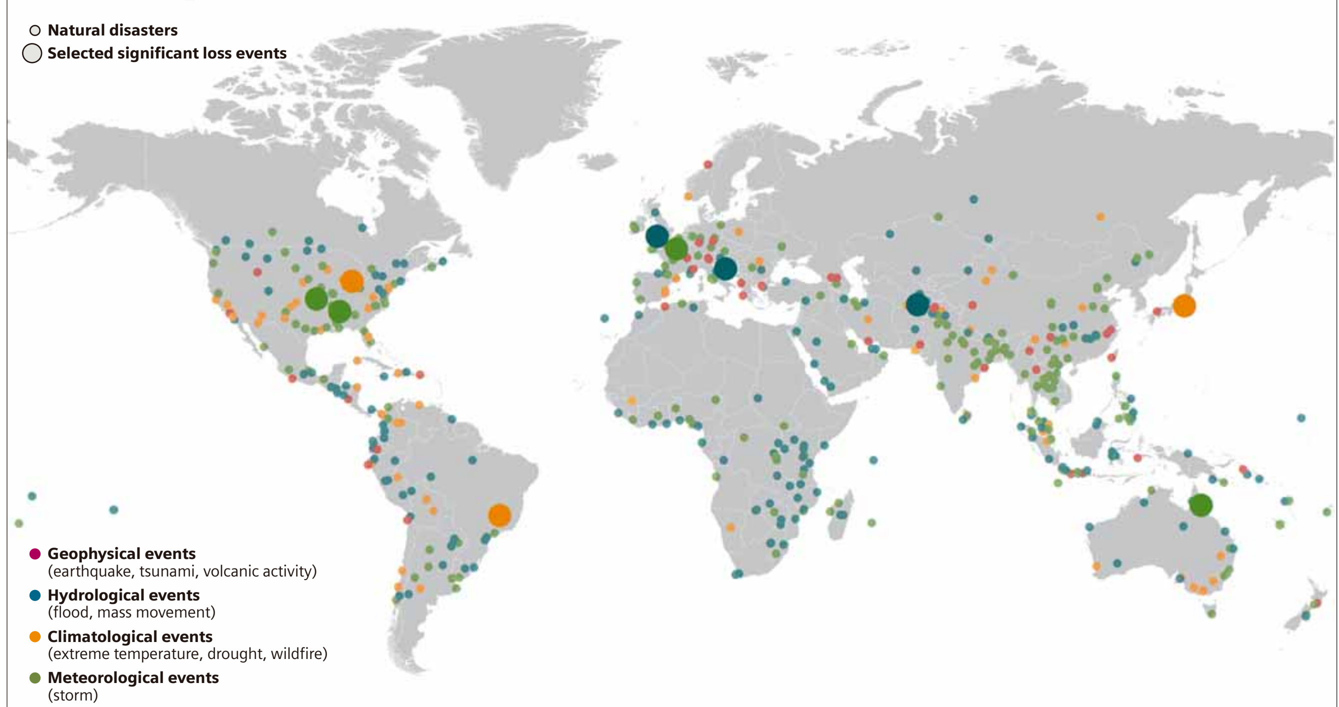
**Forecasts with Neural Networks.** This is made possible by neural networks that distinguish between typical deviations and unusual anomalies. The associated software was developed by Siemens' former "Neural Computation" department in the late 1990s and has been steadily enhanced since then. Today this 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 people to implement 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 Waternet 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 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 use to protect lives." *Sandra Zistl*

World Map of Natural Disasters in the First Half of 2014




Source: 2014 Münchener Rückversicherungs-Gesellschaft, Geo Risk Research, NatCatSERVICE — as of July 2014

*Find out how levee monitoring works in detail at: www.siemens.com/pof/levee*





# 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 anomalies in a person's breath that could indicate an illness. In the first step of this process, researchers have developed a sensor for detecting asthma. They are now going a big step further by developing a system for the early detection of lung cancer. "We first had to find out which molecules the sensor has to react to so that it can make a definite diagnosis of lung cancer," explains 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. 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 healthcare 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 be made with the help of a computer tomograph, for example.

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

*Take a look inside Prof. Fleischer's lab. He explains in a video what breath sensors can do: www.siemens.com/pof/breath-diagnostics*

# 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.**

Every time I stand here I become thoughtful. On the one hand, I enjoy the fantastic panorama of the mountains in one direction and the broad plains in the other. I breathe in the scent of the flourishing meadows, and I'm happy to be standing with my grandson in a place where I went for walks when I was a child myself.

And every time I'm here I realize once again how much was at stake back then. There's no telling what would have happened to this beautiful countryside if we hadn't convinced voters to accept a few major electricity transmission projects and wind parks. I can't believe the public debates people were having! Ever since the nuclear reactor accident 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 $CO_2$. 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.

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 recreational 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. And when the sun isn't shining, electricity comes from the gas-fired power station down there that's fed with hydrogen. And did you know that the power for the company Dad works for comes from very far away? He told me so."

I nod. Of course I know that. Back when I was a state minister, I was an advocate of long-distance electricity transmission systems that would connect the big wind farms in the North Sea and the Baltic Sea with our Alpine foothill region. The technology was improved to the point where they could supply power almost around the clock. Public acceptance of the transmission lines grew when it became financially feasible to lay the cables underground in regions with beautiful landscapes instead of having them run above ground. When I was a child, there were many more power pylons in the landscape than there are now.

"You spent your last summer vacation at the North Sea..." I say to Max. His eyes light up, and he interrupts me excitedly. "It was great! We went sailing with the fishermen. They caught a net this big full of crabs!" he says, stretching his little arms out as wide as he can. I smile and stroke his hair. "I bet that was really fun. The electric power that your dad told you about comes from there. The wind turbines are out there in the sea." "It comes from so far away?" Max looks at me doubtfully. "Yes, either from there or from solar power plants in southern Europe," I add.

I also played a role in the plans to forge ahead with the European super grid, because I was convinced that all of Europe would benefit only if they generated renewable energy in the places that would supply the most power and if that power would then be transported to the places where it was needed.

**Smart Super Grid.** "Is it true that cars used to run on oil?" Max asks me, now fully involved in the discussion. I tell him that for a long time fuel was transported to us from places even further away than Norway. Max, who is nine years old, only knows cars that run on electricity or gas — hydrogen or methane. And he finds it entirely normal that cars sometimes even feed energy back into the grid.

It seems unbelievable that we Europeans actually managed to create a smart super grid in which every region supplies exactly the kinds of renewable energy that its natural conditions enable it to produce. Together with all of the small local energy suppliers, the high-performance energy storage facilities, and the ultramodern gas power plants whose $CO_2$ emissions have been reduced to an absolute minimum in the past 50 years and which also supply district heating, we have actually reached our ambitious goal: a stable energy supply without nuclear power plants, coal, or oil.

**Learning Systems.** "Our teacher always says that we live in a wonderful place, because we were the first ones to have lots of new things and a big company tested a lot of things here, and that was really smart. They also had computers back then that knew what was going to happen ahead of time," Max tells me. "Do you mean learning systems? Your teacher was absolutely right," I answer. "Your village was used as a test area. The people there installed biomass power plants, wind turbines, and energy storage facilities. And of course lots of solar panels. You can see them shining in the sun down there in the valley. And they equipped their houses with measuring devices and sensors that made the houses smart. Now, lots of people are doing the same thing, but your village was the very first one."

Max squints and gives me a mischievous look. "You know, Grandma, I think it would be really smart to go down now and buy ice cream cones. I'm a learning thingy too, and I know that right about now there won't be a long line." *Sandra Zistl*

# TOMORROW'S ELECTRICAL SYSTEMS

**Best of *Pictures of the Future*, Spring 2015**

## 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 IRENE is being replaced by IREN2. 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 manner 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 IREN2 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.

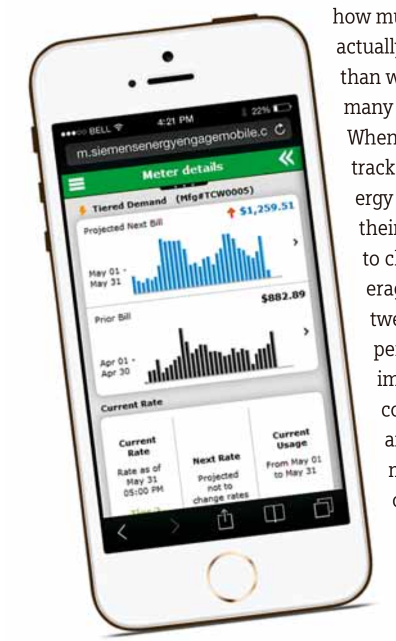
## Power Plant Breaks Three World Records

**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 300 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 Fortuna unit is an extremely powerful SGT5-8000H gas turbine from Siemens, which has already been 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 outputs.

*More information on this record-breaking plant in PoF Digital at: www.siemens.com/pof/lausward*

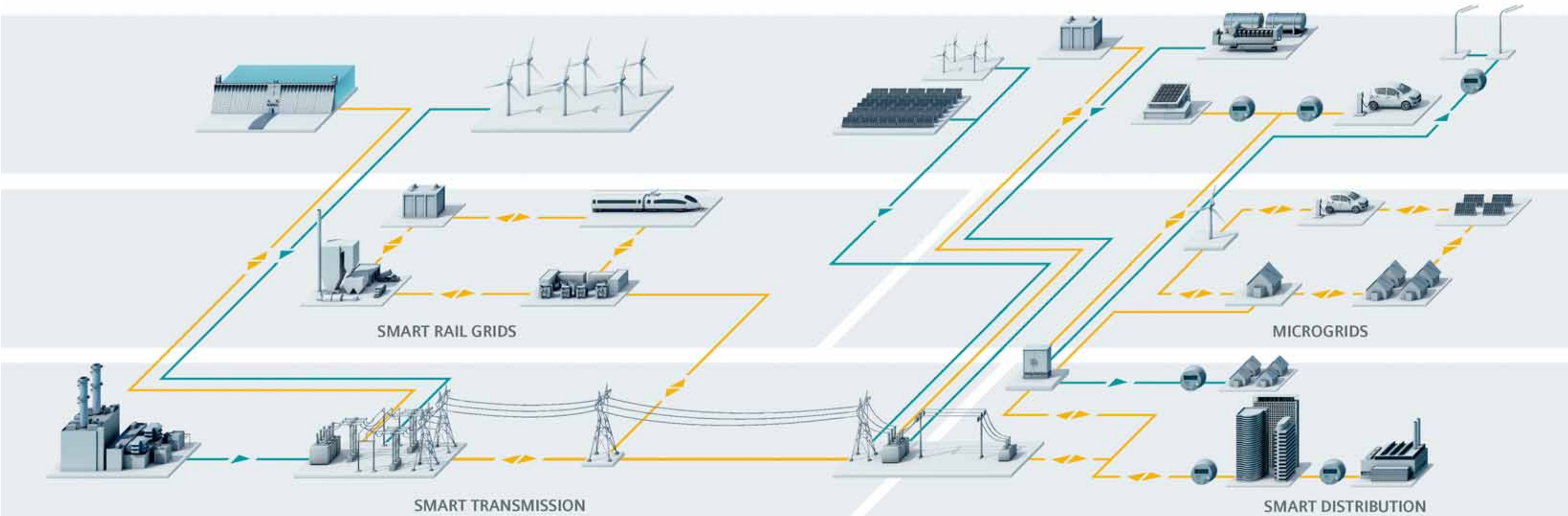
## Knowledge Is Power

**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're 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 of magnitude significantly reduces stress on the grid.




## 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 BayINVENT 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 between the grid of the Augsburg municipal utility company and a facility operated by MTU onsite energy (MTU), which manufactures cogeneration plants.




**Smart grids balance electricity supply and demand, thus helping to avoid network overloads.**

# 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 offset fluctuations in demand by starting up gas-fired power plants or using pumped-storage electrical power stations. As a result, there weren't really any unwanted fluctuations in electricity production.

But power generation has become more complicated since many countries began to focus on renewable sources of energy. Whereas Germany had several hundred large and medium-sized power plants 20 years ago, it now has almost 2 million energy producers, including roof-mounted solar panels, wind turbines, and biomass facilities. Households, commercial buildings, and industrial facilities are increasingly turning into "prosumers" — consumers who also produce energy.

As a result of these developments, smart grids are 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. An example of this is the South German village of Wildpoldsried, which generates six times as much electricity from renewable sources as it consumes. A smart grid ensures that fluctuating energy supplies from solar, wind, and biogas facilities don't threaten the stability of the network. Software agents from Siemens regulate the interaction between energy consumers and producers within the village's smart grid. Another example comes from Italy, where smart grids are becoming popular, according to smart grid expert Tullio Salmon Cinotti (p. 46). Siemens and researchers from the University of Genoa have built a micro-grid at the university's campus in Savona that could serve as an effective concept for cities (p. 44).

**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 downwards 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.

In the future, it may also be possible to use multimodal energy systems, which combine a variety of different forms of energy into a single system. Instead of being fed into grids, electricity could then be converted into thermal energy — for heating or cooling — or into chemical energy. For example, surplus electricity can be used to generate environmentally friendly hydrogen in electrolysis plants. The resulting hydrogen gas can then be used to power fuel cell vehicles, for example. The next step would be to use a catalyst to generate methane from hydrogen and carbon dioxide. This synthetic natural gas could then be fed into the natural gas network, stored in underground caverns, or converted back into electricity by gas turbines.

Moreover, electricity can be temporarily stored in the batteries of buildings and electric cars. Researchers at Siemens are also developing a facility that would use surplus energy from renewable sources to convert carbon dioxide into valuable carbon compounds for industry. The next step on the road to a truly renewable energy economy will be to make this happen directly using sunlight, similar to the way plants do this with photosynthesis (p. 50). Researchers' ultimate aim is to create modules that can be attached to buildings, where they would use sunlight and atmospheric carbon dioxide to produce energy-rich molecules such as methanol. *Sebastian Webel*

## 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 begin producing large amounts 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 project 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 projects in that it will be equipped 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/electrolyzer***

The University of Genoa's Savona campus features a groundbreaking microgrid. In addition to conventional and renewable energy sources, such as parabolic solar power, the grid uses electricity storage.

# 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 into 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 $CO_2$-free heat, such a concentrated solar power system (CSP) also produces electricity in a sustainable manner. Large CSP facilities with high-megawatt outputs are already operating in Spain and California.

But CSP facilities can also be used on a small scale in the middle of cities — cities like Savona, which is located around 45 kilometers from Genoa in northern Italy. The three parabolic reflectors installed there produce three kilowatts of electrical energy and nine kilowatts of thermal energy. They are part of a unique project that has created the first microgrid in Italy. The grid entered service in early 2014 and will now serve as a reference for similar solutions in entire cities and regions. In the future, such intelligent distribution networks will integrate various conventional and renewable energy sources, as well as electricity storage devices and controllable energy consumers, to create an energy supply system that is both environmentally friendly and reliable. Self-sufficient microgrids generate energy close to end consumers and are an indispensable part of the development of the distributed energy systems of the future.

**New Solutions for Microgrids.** Siemens is working with research partners such as the University of Genoa to develop new solutions for such microgrids, which will supply energy to communities, municipalities, and companies in coming years. The Smart Polygeneration Microgrid (SPM) project is a joint undertaking of the University of Genoa and Italy's Ministry of Research. Siemens was commissioned to build the complete system.

Since the launch of the microgrid, the campus itself has been generating around half of its annual energy requirement of one gigawatt-hour. Its three CSP parabolic mirrors are supplemented by one photovoltaic facility with 80 kilowatts maximum output and three micro gas turbines with 250 kilowatts of electrical output and 300 kilowatts of thermal output.

**Real-Time Energy Monitoring.** The SPM supplies energy only to the University of Genoa's campus in Savona. "However, our campus is very similar to a complete urban neighborhood because it encompasses apartments, offices, a cafeteria, and repair shops," says SPM project director Professor Federico Delfino. "Our campus covers 60,000 square meters and has ten buildings that are used by around 1,700 students every day."

The centerpiece of the SPM is the SICAM Microgrid Manager, which links Siemens' Decentralized Energy Management System (DEMS) and the SICAM PAS SCADA 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 all of these components were designed to be used with proprietary monitoring programs 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. SICAM PAS, 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 $CO_2$ 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 Center that will demonstrate how energy distribution in entire cities will be optimally managed in the future. *Christian Buck*

*For more on energy-saving systems, visit PoF Digital at: www.siemens.com/pof/savona*

# Smart Grids — The Perfect Base for Innovative Services

**Tullio Salmon Cinotti** (65) is an Associate Professor of computer architecture, logic design, and interoperability of embedded systems at the University of Bologna. He is the coordinator of the University of Bologna's participation program in European research initiatives in the areas of electric mobility, energy efficiency and smart spaces.

**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 and 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*

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





# Why Finland Has Europe's Most Advanced Grid

**Jan Segerstam** (40) studied at Aalto University in Helsinki, Finland, and received his EMBA (Executive Master of Business Administration) degree there. As Development Director at Finnish energy sector service provider Empower IM Oy, he has worked on a number of Europe-wide programs for the development of the Internet of Energy.

**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 automated 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/segerstam*

In wind parks, front row turbines are exposed to the most intense winds. Those behind them are often disadvantaged by powerful eddies that reduce their efficiency. Volkmar Sterzing (right) is studying how to optimize output even in light winds.

# Optimizing How Wind Turbines Work

**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.**

In 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 and to 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 in and 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.

Why should we optimize wind turbines? The answer is simple: Wind turbines don't always run at full capacity. They deliver far less energy than they potentially could – especially when the wind is weak or only blowing at half strength. "We want to increase their performance by a few percentage points in precisely these situations," Sterzing explains.

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.

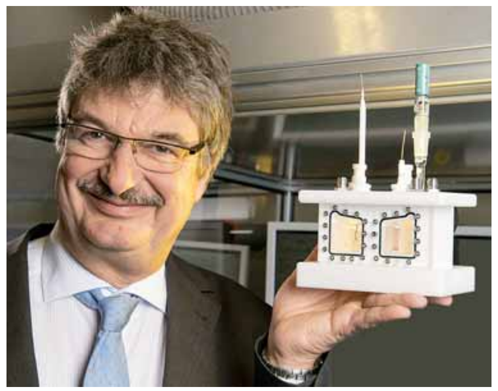
## Machine learning is helping to reduce the costs of wind energy, thus making it more competitive.

"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 doing 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. *Ulrich Kreutzer*

*See fascinating images of on- and offshore wind farms at the PoF image gallery: www.siemens.com/pof/windturbines*

*Volkmar Sterzing explains how wind turbines learn from experience: www.siemens.com/pof/machine-learning*



# 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.**

There is probably no other chemical reaction that is as productive as photosynthesis — a biological process that uses the energy of light and water to convert $CO_2$ into energy-rich substances such as sugars inside plants. Scientists estimate that plants produce around 150 billion metric tons of energy-rich biomass worldwide every year. In view of this, researchers are investigating ways of replicating the biomechanisms involved in photosynthesis.

Unfortunately, they haven't been very successful so far. Photosynthetic processes involve many closely interconnected and extremely complex protein structures based on precisely-defined atomic arrangements that cannot be easily replicated in the laboratory. As a result, scientists have so far failed to achieve their dream of using sunlight to operate an efficient biochemical "factory."

However, developers at Siemens Corporate Technology (CT) in Munich have now come a big step closer to making the vision of synthetic photosynthesis a reality. They did this by creating shoebox-sized modules in which carbon dioxide is energetically stimulated in the same way as in plant cells. Depending on the testing conditions, the activated $CO_2$ reacts to create a variety of other molecules such as ethylene, which the chemical industry needs for the production of plastics. $CO_2$ can also be converted, for 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 $CO_2$, 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 "$CO_2$toValue." "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 $CO_2$ and converting it into products. To do this, they are using electricity generated from renewable sources.

**Working with Universities.** The key elements of the $CO_2$toValue project are chemical catalysts that charge inert $CO_2$ 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 range with a large surface . The catalysts that Schmid developed in cooperation with university partners are already very effective at converting a large part of $CO_2$ into the desired products.

**Photosynthesis in Electrolysis Cells.** Fleischer looks through two Plexiglas windows at a bubbling reaction that is taking place inside a small photosynthesis module. The module is basically an electrolysis cell, in which a current is conducted through electrodes into highly-carbonated water, that functions as an electrical conductor.

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 $CO_2$ 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 $CO_2$ 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.

Corporate Technology researcher Sofie Romero Cuellar with an electrolysis cell. Electrolysis modules have been developed at Siemens under the direction of Prof. Maximilian Fleischer (left page). In these modules carbon dioxide is converted into valuable substances in ways that resemble processes in plants.

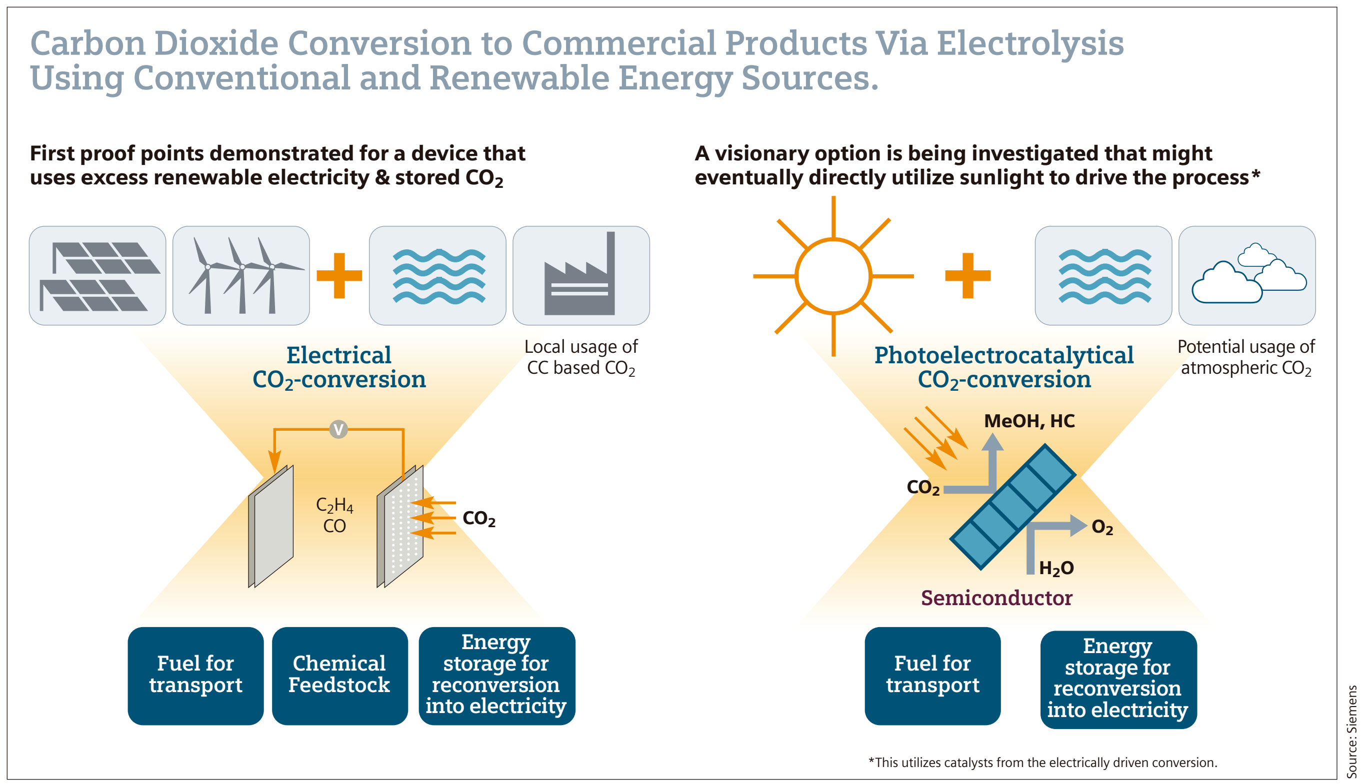
## $CO_2$ extraction modules could cover building facades and convert the gas into biofuel.

"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 $CO_2$ 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 $CO_2$ from the exhaust produced by power stations, factories, and chemical plants. Subsequently, however, it will use $CO_2$ from the atmosphere. With a view to accomplishing this, researchers are developing materials capable of absorbing $CO_2$ 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 $CO_2$ 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 Schröder*




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.





Thanks to Caterva, Andreas Seubert can use much of the electricity produced by his photovoltaic modules himself. An app shows him how much he uses and how much is fed into the grid.

# 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.**

In his rural home in Bavaria, Andreas Seubert has a 1.8-meter high steel cabinet in the basement that houses stacks of lithium-ion batteries on one side, while the other side contains inverters, a smart meter, electronic switchgear, and a card-size circuit board with a processor and a mobile communications unit. Together with a number of solar panels on the roof, the systems provide an impressive example of what experts mean by decentralized power distribution.

If Germany succeeds in its energy transition, energy storage systems (ESS) such as the one in Seubert's basement will become an important part of a sustainable energy network in the future. That's because such systems will help keep grid frequency stable and offset power deficits when the sun isn't shining and the wind isn't blowing. This task is currently still performed by conventional 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 Brehler. 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 (kWh). 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" in order to offset fluctuations, Seubert explains.

This innovative concept was originally developed by Siemens Novel Businesses (SNB,

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 various departments at Siemens Corporate Technology until the basic version of the swarm software was completed. Experts at SNB also helped establish Caterva, because it is their job to create new companies whenever a promising business idea cannot be further developed by Siemens AG as well, as quickly, or as flexibly as by an external firm.

Before becoming the managing director of Caterva, Brehler gained extensive experience at another Siemens spinoff: EnOcean GmbH. Siemens will continue to support Caterva in many ways in the future. For example, it connects the cabinets to all of the hardware and is also a minority shareholder in the company.

**Pilot Test.** Several months ago, in cooperation with energy supplier N-Ergie, Caterva launched a pilot test in which about 65 private photovoltaics owners will eventually take part. Banks of batteries in their homes enable these owners 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 just 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 relatively little of it himself. Although the electricity that is not immediately used is fed into the grid and Seubert is paid for it, his long-term goal was to become independent of energy suppliers.

He thought it would be unprofitable for him to buy the batteries for storing the solar power. "Experts advised me against it, because they still consider high-performance batteries to be too expensive for private households," he says. By chance, he found out about the Caterva project. "My colleagues at Siemens who are working on technologies for smart grids told me how batteries and smart technology could make me part of the energy supply system," says Seubert. After he registered to take part in the pilot project, Caterva installed its new ESS unit in his basement in the early summer of 2014.

People like Andreas Seubert are the pioneers that Caterva needs in order to demonstrate the swarm concept's capabilities. The same applies to N-Ergie, which is involved in the pilot project. "We are working hard on ways to implement the energy transition," explains project manager Ingo Sigert from N-Ergie's Strategic Corporate Development unit. Sigert is convinced that energy supply companies will have to offer innovative solutions in order to survive on the market over the long term. That's why N-Ergie recently put a 70-meter hot water heat storage system into operation. The storage system, which is one of the tallest in Europe, is connected to a combined-cycle plant that has an integrated biomass heating station.

One of the main issues that N-Ergie is addressing is how to solve the problem of energy storage and grid regulation in a network characterized by widely fluctuating amounts of electricity from renewable sources of energy. "We were immediately captivated when Caterva came to us and presented its swarm concept," explains Sigert. The two companies quickly agreed to form a partnership and also brought Friedrich Alexander University (FAU) in Erlangen on board. Scientists from the university will support the pilot project until 2017. "We can now gain experience for a time in the future when more and more electricity will be obtained from renewable energy sources," says Sigert.

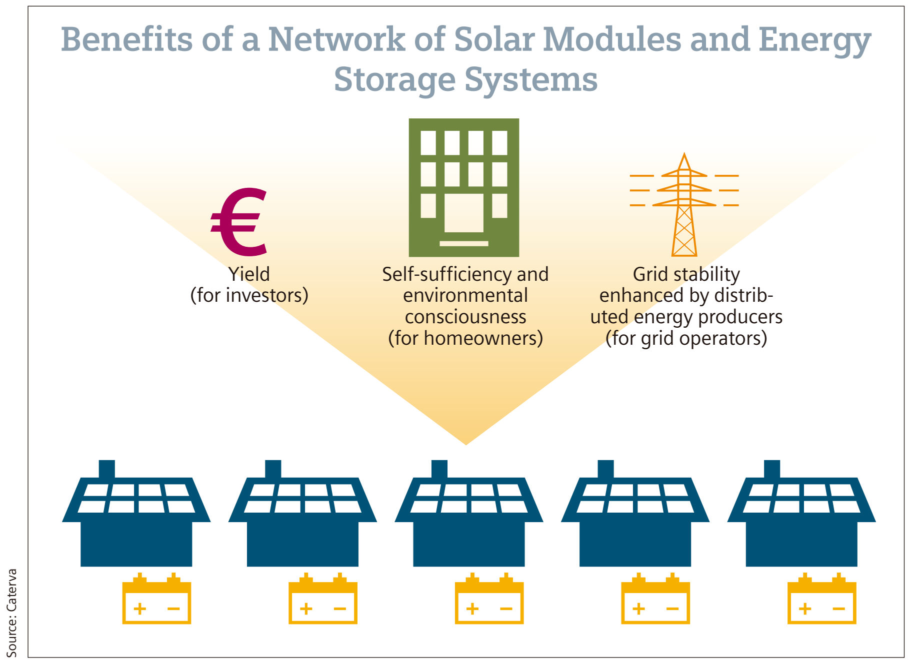
## Energy storage systems enable private solar panel owners to use more of their own power.

**Positive Response.** Each project partner is responsible for specific tasks. N-Ergie contacts customers in its grid area who have relatively new solar panels installed on their roofs. "The response has been very positive. We quickly found more than 25 potential participants 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 rental fee for this service. This fee amounts 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 kWh — and the amount that the use of their own electricity would cost them. This currently results in savings of 10 to 15 ct/kWh. Caterva can offer such favorable rental terms because of the income it gets from supplying primary controlling power to the transmission grid operator.

N-Ergie, in turn, provides the overarching infrastructure. In the future, its control center will manage not only the company's power plants but also the Caterva project swarm. "One of its key tasks is coordination of the swarm," says Brehler. Mobile radio is used to transmit data from ESS units in participants' basements to the control center. As a result, N-Ergie knows the batteries' charge levels at all times.

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 generate too much electricity or when conventional 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 production and consumption can be offset and grid frequency kept at 50 hertz. This is traditionally done by conventional power stations such as gas-fired power plants.

Since 2011 Germany has also allowed distributed energy producers to perform this task, provided they feed at least 1 megawatt of controlling power into the grid. In its system 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 technologies such as those from Caterva. "We have to act now so that we will have solutions to keep the grid stable five years from now," says Brehler.




Linking photovoltaic modules and energy storage systems to create synchronized swarms produces many benefits — for investors, homeowners, and grid operators.

### How Siemens is Testing New Business Models

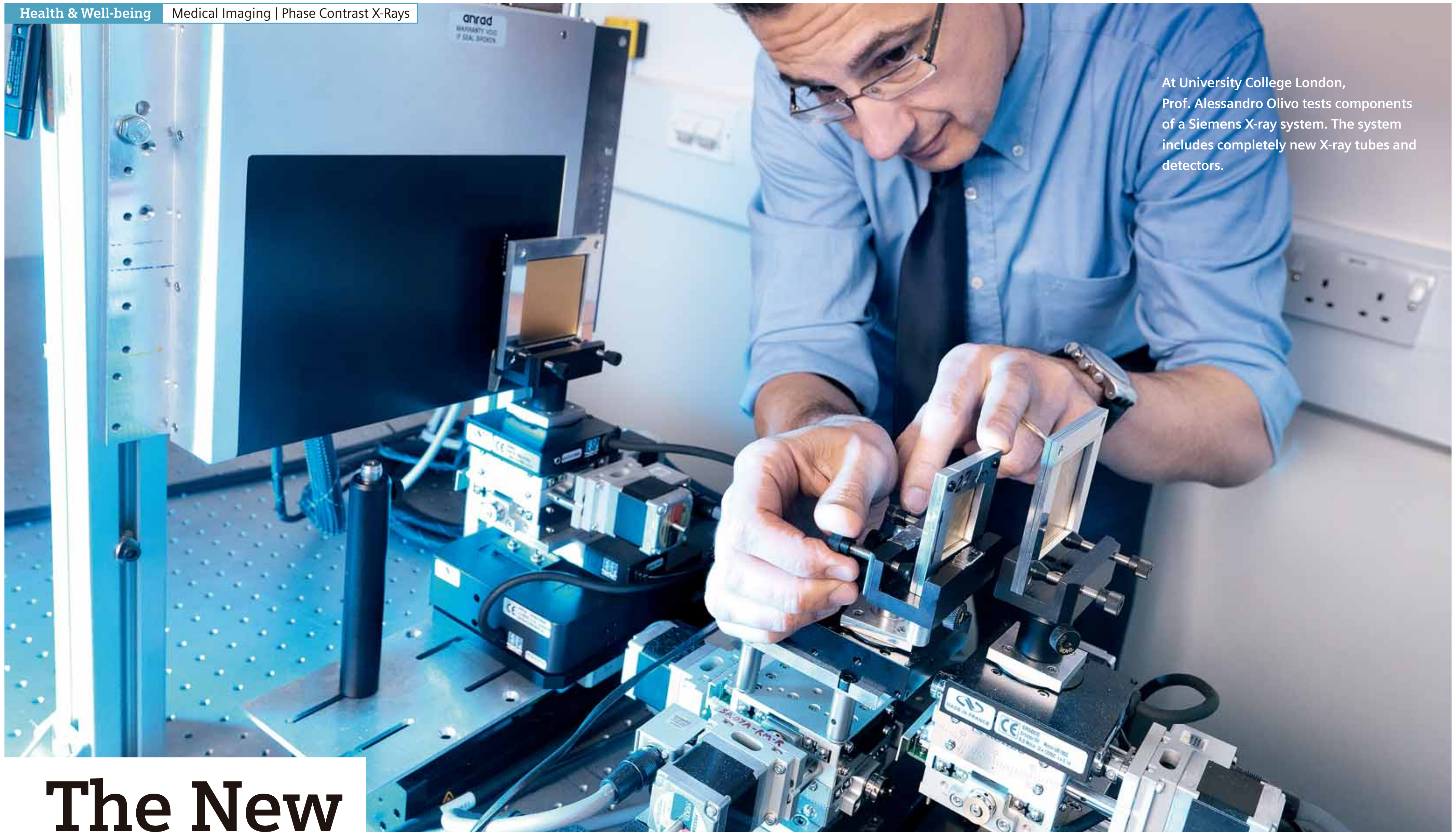
Siemens Novel Businesses has been a part of the Innovative Ventures department at Siemens Corporate Technology since 2012. Its mandate is to establish startup companies in fields of business that could be of interest to Siemens. In doing so, it creates opportunities for quickly and flexibly testing innovative business models. Such startup companies are managed independently of Siemens and led by experienced entrepreneurs. Siemens Novel Businesses finances these companies just as a venture capital investor would. Siemens can later decide whether it wants to incorporate these startups into its organization so that their business operations can be expanded within the company.

**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 success. The participants' ESS units are supplemented by a Caterva app, which always displays the household's electricity consumption 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-Ergie 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 controlling power is supplied.

This pilot project, which was only recently launched, is just the beginning of a far-reaching development. N-Ergie is thinking of integrating owners of photovoltaic modules from all over Germany, because "the bigger the swarm, the bigger its contribution to grid stability," says Sigert. Germany is especially well suited for the implementation of the Caterva concept, whose slogan is "Mit der Sonne im Netz" (Into the grid with the sun). At approximately 1.1 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 convinced of this as well. "We are now looking for infrastructure investors who are interested 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 one day have enough energy for my household even if there is a widespread power outage," he says. "I would even be satisfied if I had enough energy to watch an important soccer game on TV." That should already be possible today.

*Katrin Nikolaus*



At University College London, Prof. Alessandro Olivo tests components of a Siemens X-ray system. The system includes completely new X-ray tubes and detectors.

# 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 matter with ease, and he quickly recognized how useful this type of radioscopy could be for medical imaging and diagnostics. Two days 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 transillumination 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 dark in an X-ray image, while soft tissues appear light.

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 300 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 revolution in medical diagnostics," says Dr. Heinrich Kolem, 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 Kolem, it include the Components and Vacuum Technology team at Siemens Healthcare lead by its CEO Dr. Peter Molnar. 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.

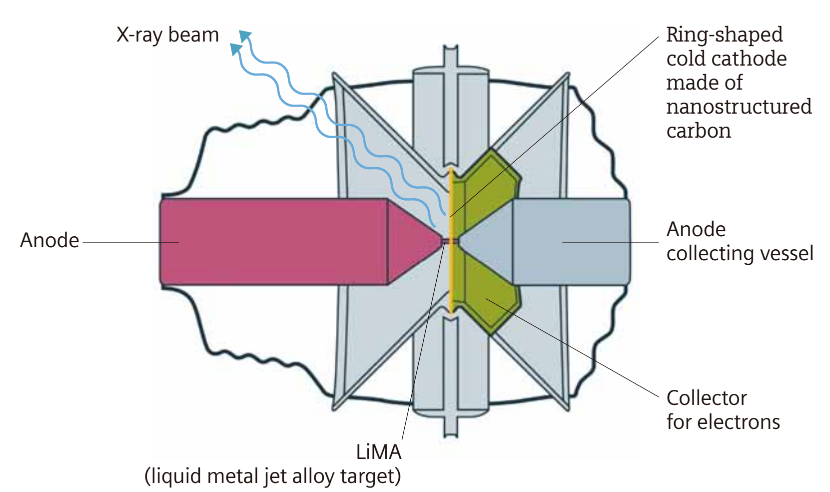
Electrons no longer collide with a solid target of tungsten, but with a new device invented by Siemens researchers that they've named LiMA, which stands for "liquid metal jet alloy" target. In other words, the electron target is a jet of liquid metal as thin as a human hair. The metal consists of 95 percent lithium and 5 percent heavy elements such as bismuth or lanthanum. The latter produces 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 light 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 radiation is four billion times brighter than the sun on the surface of the earth," says Heid, "which results in a 20-fold higher imaging resolution."

**Image resolution is 20 times higher than before — thus allowing phase contrast to be measured.**

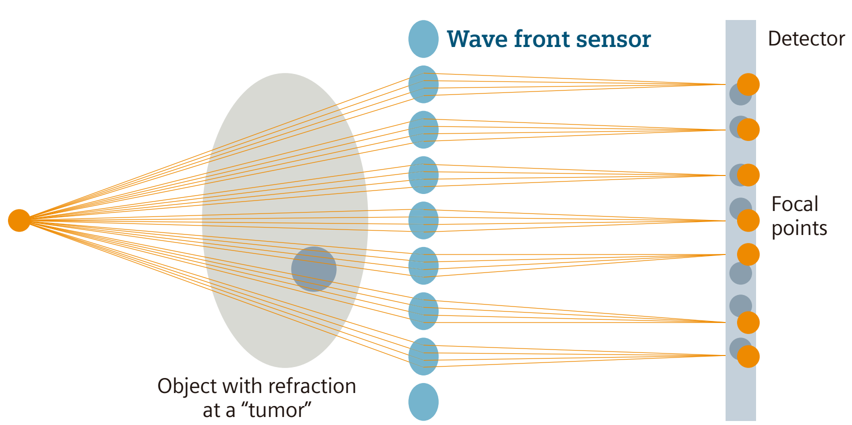
## Phase contrast imaging would make it possible to distinguish different soft tissues.

### Siemens' Next-Generation X-ray Tube




**Siemens' next generation X-ray tubes will be completely different from today's. Electrons will no longer come from a hot cathode, but from a cold cathode ring made of nanostructured carbon. The X-ray light will be generated in a thin jet of liquid metal, rather than at a solid anode.**

### How a Wave Front Detector Works




**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 same 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 optics 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*





**A model of the mitral valve as calculated by eSie Valves (green-blue mesh with yellow contour) and overlaid on a 3D TEE, full volume ultrasound acquisition. Brown areas show heart tissue, while the red-blue cloud is a color Doppler image showing the direction of blood flow. In this case, some blood (red) abnormally crosses the valve.**

# 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.**

*See eSie Valves in action in a PoF Digital video: www.siemens.com/pof/cardiac-valves*

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 therapies 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[1], in the U.S. valve surgeries 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[2] 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.

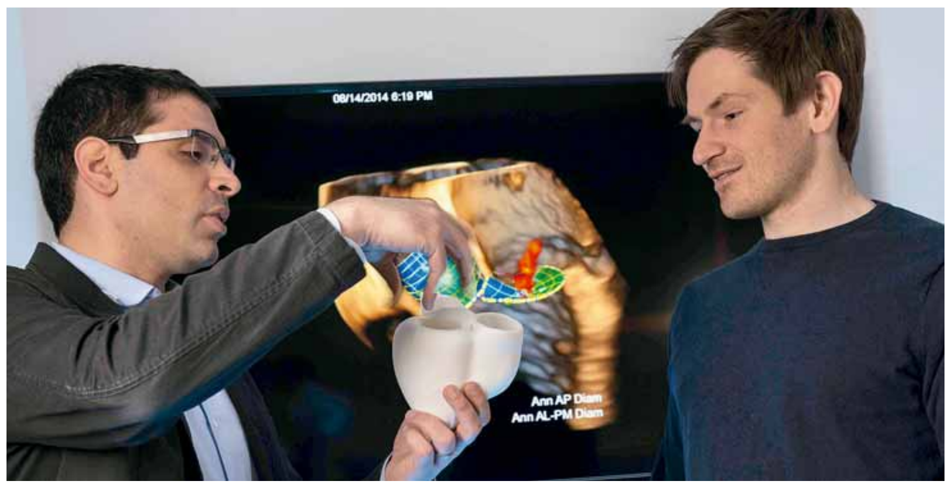
**Precision Procedures.** As it delivers a comprehensive assessment, echocardiography is the basic imaging method for assessing cardiac status. If significant valvular disease is detected, surgical valve repair or replacement may be indicated. But because both therapies are open heart procedures, many patients cannot benefit from them due to age-related contraindications. In view of this, over the last five years interventional therapies have



1 http://circ.ahajournals.org/content/123/4/e18.full.pdf
2 http://health.costhelper.com/heart-surgery.html

become a valid therapeutic option. Such therapies are much more patient friendly compared to open heart surgery. For instance, TAVR in severe aortic valve stenosis and mitral clip therapy in severe functional mitral regurgitation may benefit from Siemens' new TEE probe, while eSie Valves may help to improve diagnostic assessment, analyze intraprocedural results, and monitor valve prosthesis functions during follow-up.

To visualize a valve's anatomy and function, a cardiologist would inch the new transesophageal 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 eSie Valves, an advanced analysis semi-automated 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.




**Tommaso Mansi (left), who participated in the development of the algorithm that drives eSie Valves (image on monitor), explains how the software works to colleague Sasa Grbic.**

"At that point," explains Tommaso Mansi, PhD, a Senior Key Expert with Siemens Corporate Technology (CT) who participated in the development of the algorithm that drives eSie 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 patient's actual valve." The result, he says, is a personalized model of the valve. Finally, the cardiologist clicks "analysis" and eSie 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 visualization 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 annulus varies throughout a cardiac cycle," says Mansi, who explains that competing commercial 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, "eSie Valves provides automated, objective and reproducible measurements of the aortic and mitral valves in seconds. This quantitative information allows physicians to quickly and easily evaluate valvular anatomy and physiology, which increases diagnostic accuracy and confidence. Furthermore, in patients scheduled to undergo surgical or interventional therapies, it helps in planning the procedure."

**Seamless Images.** This is particularly important when it comes to the mitral valve. Unlike the aortic valve, the mitral valve's leaflets, which control the flow of blood from the left atrium to the left ventricle, are held in place by muscles that make minimally-invasive treatments with current technology difficult. As surgical mitral valve therapy always needs an open heart approach, comprehensive cardiac and valvular assessment is 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, "cardiac surgeons have had to make many of their mitral valve treatment decisions when the heart was open. But eSie Valves, which is based on real-time 3D TEE data, is now enabling highly accurate diagnostic assessment, so that cardiac surgeons will hopefully no longer be surprised by the real anatomy. In short, eSie Valves is bringing valvular assessment to a new level of objectivity."

In addition to the advantages offered by eSie Valves software, its associated ultrasound 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 eSie 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 irregular heartbeats or an arrhythmia." She points out that, to get sufficient temporal resolution, competing systems stitch images from consecutive heart cycles together to produce continuous ultrasound volumes, which have the shape of a pyramid. "Our technology acquires this information in continuous imaging. 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 eSie Valves technology in conjunction with the recently-introduced real-time 3D TEE probe represents an important milestone toward personalized cardiac care, it is just the first step down the road to a much more ambitious vision. What researchers eventually hope to achieve is to model a patient's entire heart, including hemodynamics – the movement, volume and pressure of blood – and to be able to perform therapies on that personalized model with a view to optimizing therapeutic 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 technology behind eSie Valves is generic," says Mansi. "This is not just a one-shot application. And that is its key differentiating factor: It offers the potential of opening up a world of new applications. It just depends on what you want to apply it to." *Arthur F. Pease*





# A Glance behind the Scenes

**Ever wondered what it's like to stand on top of a wind turbine on the high seas? Or see how a gas turbine is manufactured? Want to walk through the world's longest railway tunnel? Or take a close-up look at a rocket on a launch pad? How about a glance behind the scenes of Munich's Oktoberfest? We invite you to do all of these things in our interactive 360° features.**

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# 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.**

It 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…Well, 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 manufacturing engineer less. Adiós, muchachos! And then, one day, the technology to bring me back had arrived – and been applied. I could feel myself swimming upwards as if out of a bottomless well. My eyes opened. Androgynous doctors swam into view. "Mr. Turner… Ambrose…how are you feeling?" they had said.

**Printing Cells.** During the following days, as my mind had cleared and my body regained its strength, I learned about the bone and organ regeneration techniques that had restored me to health. Robotic systems outfitted with extraordinarily fine needles had aspirated the damaged parts of several of my organs and bones, produced in-vivo scaffolding for the replacement structures, and then colonized the scaffoldings with my own stem cells using 3D printing. Layer by layer, in a process that we used to call additive manufacturing when I was a young engineer, the robotic arms had tirelessly rebuilt parts of my body from the inside out.

Considering my manufacturing background, all of this was an exciting introduction to the world I had woken up in. But I have to admit that what I really wanted to know about was hands-on stuff – things like turbine blades, metals, coatings, manufacturing techniques… and Giuseppe, my old compadre in the blade design department. What the hell had happened to him over the last 40 years? He too would be in his mid-70s by now – almost retirement age according to the "re-socialization" information they had bombarded me with at the hospital.

**Empty Highways.** "Let you out on good behavior, did they?" Giuseppe gave me his old wry smile as he slapped me on the back when we met two weeks later. It was a lovely spring morning and we were on our way across the glistening Scottish countryside to the site of our old manufacturing plant. How pristine and free of industrial blemishes the landscape is, I thought as our vehicle glided along a surprisingly empty motorway and turned off at our exit. A few moments later we pulled up at what might have been a large picnic area. A voice from the dashboard announced "access granted," after which the vehicle rolled forward and parked.

**Invisible Factory.** "What are we stopping here for?" I asked, looking around at the gently-sloping hills dotted with grazing sheep, wild hare, and the occasional red deer. The place reminded me of one of those "cageless" safari zoos, like the one I had visited in San Diego as a child where a baboon had suddenly lunged at me. I felt a little nervous.

"You'll see," said Zeppy, as I used to call him. We got out of the car and strolled across the cropped, wild grass, scattering small huddles of rabbits.

After a few meters we came to one of several grassy mounds that dotted the field. I still didn't have a clue as to what was going on. But then Zeppy squatted and put his palm on

the rounded surface. To my amazement, the mound became transparent.

Suddenly, I realized, we were at the edge of a huge, low bubble, looking down into a world of frenetic activity. "Welcome to our new fab!" Zeppy announced. "She entered service just a few years ago – '54 I believe."

**Underground World.** I must have looked so astonished that Zeppy added, "Oh, sorry, old pal. Forgot to explain. These bubbles – tough as steel, but they turn transparent for authorized personnel. Stuff's all based on biometrics – in this case an embedded electrophoretic layer that recognizes fingerprints and genetic signatures. The bubbles allow on-the-spot inspection of key areas – if anyone bothers to come out here, that is."

I crouched down next to Zeppy and peered into the cavernous facility. "You mean this is it?" I asked. "The production center for our turbine blades?"

"Yes, sir!" said Zeppy, with a touch of pride in his voice. "Acres and acres of it under these lovely fields."

**Co-creation Workers.** "And the workers?" I asked, remembering in a flash of memory from 40 years ago Linda, the knockout production chief who had joined the company just before my accident. "The offices? The parking lots? Where is everybody?"

"Hold on, pal," said Zeppy. "We have hundreds of workers. But you won't see many of them around here. Most of them do their stuff at home. Same thing's happening at other companies. The result is – as you noticed – empty roads, more open space, and more wildlife.

We have groups from all over the world competing against each other for our business. We call it co-creation. They work on contracts covering everything from refined particle-spray-field dynamics in additive manufacturing processes for blade surfaces to hybrid components made of multiple substances, optimized logistics, robot sensor-community hyper-perception, service prognostics, integrated security; you name it, we're doing it!"

"Now you're talkin', buddy," I said, finally starting to piece together a picture of what had happened over so many years.

**From Powders to Turbine Blades.** "Take a look down here, for instance," Zeppy went on. He pointed to an area directly below us where a series of transparent machines were connected by what seemed to be a glowing tube of pure energy. "What you're looking at," he said, "is how we add meat, so to speak, to the skeleton of each blade. We start with a pre-formed core made in another part of the plant to guarantee structural integrity. Then, in a series of steps, ceramic-, metal-, and carbon-nanoparticles are digitally sprayed onto the core. It's similar to the additive 3D printing processes we were working on before your accident, but thousands of times more precise – and effortless to individualize to the customer's needs. The result is an abrasion-resistant crystalline atomic structure that's great for burning the pure hydrogen gas produced by wind- and solar-powered electrolyzers."

"So the famous hydrogen economy finally arrived!" I exclaimed.

"Exactly," said Zeppy. "And our manufacturing technology for high-temperature blades made it possible. But there's more," he added. "During this process, microscopic sensors are laser-embedded throughout the blades, allowing each blade to deliver continuous information about its condition throughout its lifetime. Finally, to avoid micro deformations and materials contamination, the blades pass from machine to machine not on a conveyer belt, but in a powerful magnetic field that also functions as a continuous inspection system."

"I'm starting to see the light," I said. "But how do parts and products get in and out?"

"Almost everything's underground," said Zeppy. "Materials are piped in. We're talking very specialized powders. Finished products are shipped out via pneumatic pipes to a distribution center."

"And localized repairs and components – can customers do that kind of thing on their own now?" I asked.

"Oh, of course," said Zeppy. "If a blade needs resurfacing, for instance, the utility operator's robotic systems will add a layer of whatever material is needed on the spot. And they can manufacture new components locally as well. What's more, if they come up with new ideas through their own co-creation..."

Noticing a movement from the corners of our eyes, we looked up. Only a few meters away stood a large, gray wolf, it's sharp, white teeth glistened in the morning sunlight. I froze in fear. "Not to worry," said Zeppy. "It's only one of our bionic security systems. It recognizes me."

"And me?" I asked, as a hair-raising growl began to issue from the beast's throat.

"That could be a problem," said Zeppy.

*Arthur F. Pease*





## 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 Maurer German Wheels according to a plan by Bussink Design. The 74-meter wide wheel rotates two to four times per hour and can carry up to 16 passengers in each of its 27 gondolas. Mobile XL Ferris wheels are not designed for county fairs, as they take too long to

build and disassemble. Instead, the giant rides serve as temporary tourist attractions at alternating locations. The first of two record-breaking Ferris wheels is already attracting visitors to Puebla, Mexico, where safety is the top priority. For instance, a backup power supply is on hand in case of a power failure. What's more, the wheel is designed in such a way as to ensure that its heaviest point always moves to the bottom of its center of gravity. Thus, even without electric power, passengers would be able to safely disembark. Added security is provided by two redundant, fail-safe certified Simatic S7 300F PLCs.

*For more on technologies for ent tainment, visit PoF Digital: www. siemens.com/pof/oktoberfest* 360°

## Tomorrow's Workplace

**The factory of the future** will be highly flexible and organized like a living Internet in which everything, 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 Scholz and Johannes Labuttis, both at Siemens Corporate Technology in Munich, in 15 years most monotonous and strenuous activities will probably be a thing of the past. Scholz and Labuttis focus on the role of humans in production processes. The idea here is to optimally align an employee'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.

## The End of Defects

**German Chancellor Angela Merkel** was treated to key elements of the factory of the future during a February 2015 visit to Siemens' electronics plant (EWA) in Amberg, Germany. There, products already communicate with production machines, and IT systems control and optimize all processes to ensure the lowest possible defect rate. Siemens is the world's leading PLC supplier, and the EWA is the company's showcase plant for these systems. Production quality is at 99.99885 percent, and a series of test stations detect the few defects that do occur. The factory manufactures 12 million Simatic products per year. At 230 working days per year, this means that the EWA produces one control unit every second. Production is largely automated. Machines and computers handle 75 percent of the value chain on their own; the rest of the work is performed by people. Only at the beginning of the manufacturing process is anything touched by human hands, when an employee places the initial component (a bare circuit board) on a production line. From that point on, everything runs automatically. What's notable here is that Simatic units manage the production of Simatic units.

***For more on digital factories visit PoF Digital: www.siemens.com/pof/ewa***

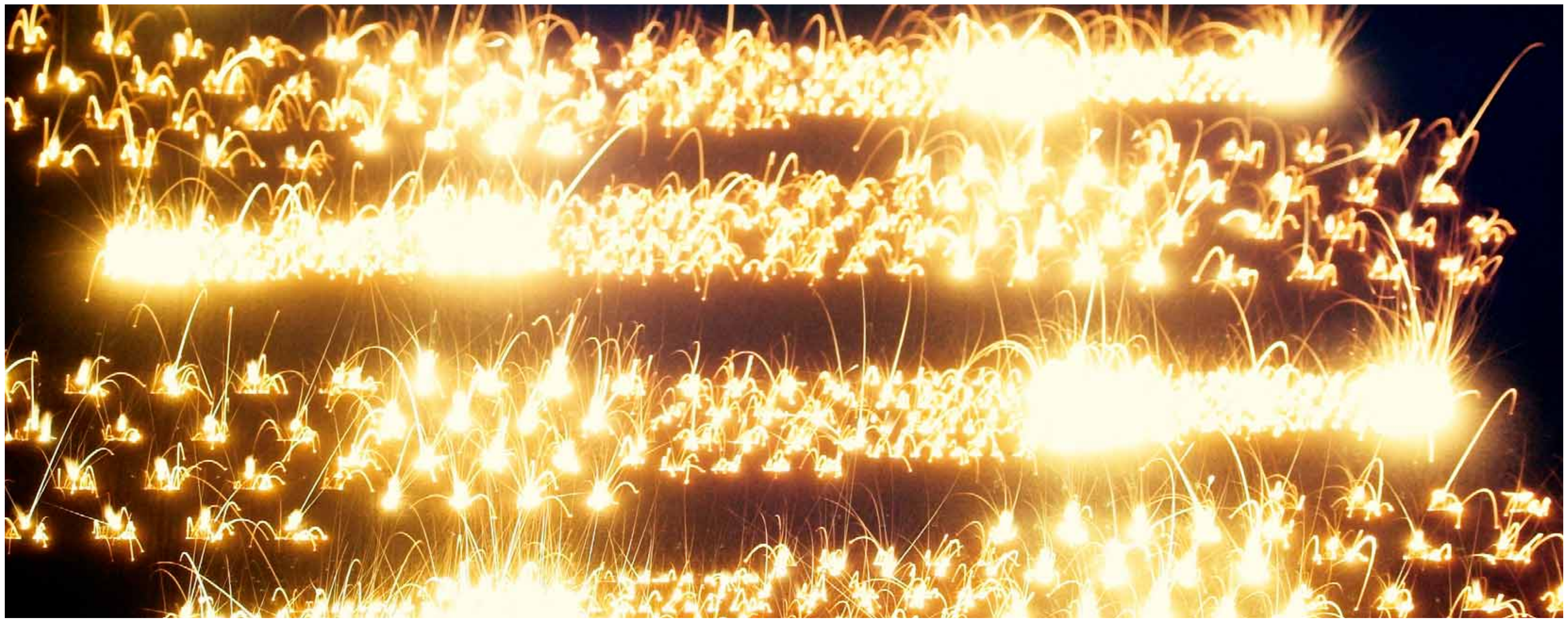
## Turbine Values in Real Time

**In the near future,** motion sensors will measure turbine values regarding wear in gas-fired power plants. Siemens' researchers would like to combine this data with additional information and evaluate it in real time. This information would cover a variety of parameters, including 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, researchers estimate that over one million Euros could be saved each year just in the servicing of turbines. Such real-time analyses are already being conducted for Siemens' latest H-Class gas turbines, where hundreds of sensors precisely measure key operating values.

# 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.**


The laser beams used in 3D printing turn powdered metals into complex objects, many of which would otherwise be impossible to produce.



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 in 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.

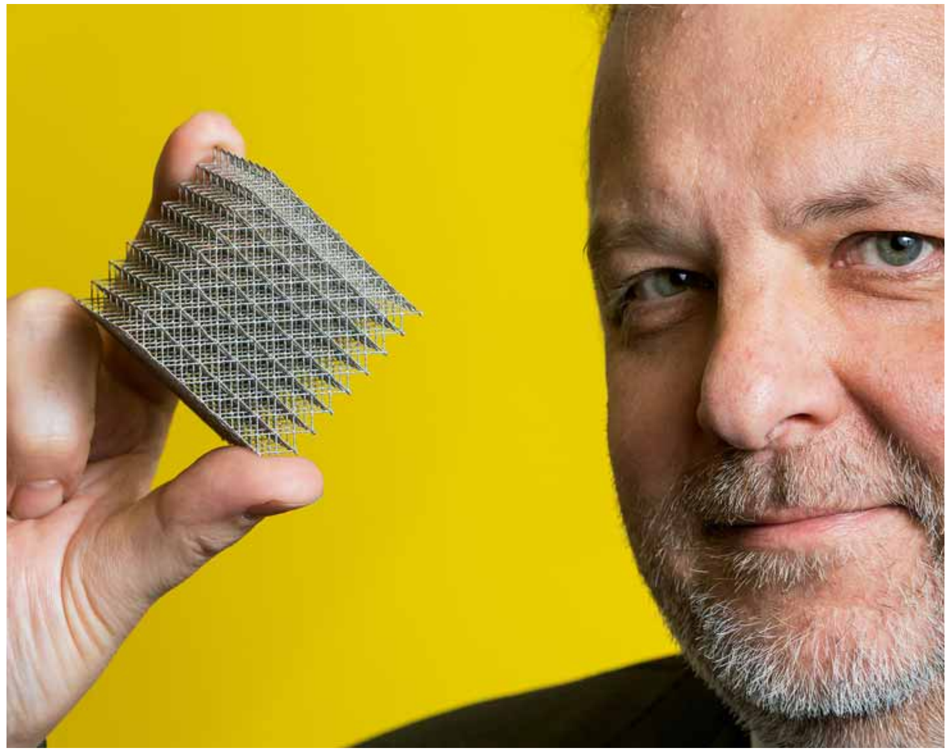
**Extremely High Centrifugal Forces.** "However, we have to make more progress before this will be possible," says Rehme as he takes a brush to sweep the fine powder off of a finished component. "It still takes a relatively long time to print each part. Depending on the object's size, it can take anywhere 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*

Using a 3D printer, Dr. Ursus Krüger produces complex components from metallic powders.



# From Particles to Parts

**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. It's 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*

*See how 3D printing works in a PoF Digital video: www.siemens.com/pof/video-3d*





# Additive Manufacturing's High Growth Future

**Although additive manufacturing** won't replace conventional production methods, it is expected to revolutionize many niche areas. As a result, exponential growth is on the horizon.

**Market Researchers Predict 300% Growth.** From the user's point of view, the additive manufacturing (AM) market can be basically divided into two sectors: the market for plastic printers that are now also affordable for private consumers, and the market for professional devices that are used in industry to "print" with materials of all kinds, including ceramic and metal powders. Although analysts still consider the additive manufacturing market to be a niche sector, they nonetheless state that it had a volume of up to €2 billion in 2012. It took the sector 20 years to reach a market value of €1 billion. The second billion was attained only five years later, and analysts now believe that it could grow at least fourfold over the next ten years.

**From Prototypes to Mass Production.** Until recently, additive manufacturing was mainly used for rapid prototyping. Prototypes are produced layer by layer in the aerospace, automotive, and machine tool production industries, as well as in the medical and dental technology sectors. According to studies conducted by the Fraunhofer Additive Manufacturing Alliance, approximately 150 companies currently operate in this services market.

Even though analysts at Wohlers Associates expect the rapid prototyping market to grow from $1.5 billion in 2012 to more than $5 billion by 2020, they anticipate the most promising market to be in quite another area. "Money will be made with manufacturing, not with prototypes," forecasts Tim Caffrey, a consultant at Wohlers. This assessment is shared by Bernhard Langefeld, a machine construction expert at Roland Berger Strategy Consultants and one of the authors of a study titled Additive Manufacturing – A Game Changer for the Industry? He believes industry is already close to the large-scale production stage in the use of AM to create metallic structures for selected products in medicine and aviation. Additive manufacturing is already a reality for making artificial hip joints and crowns for teeth, for example.

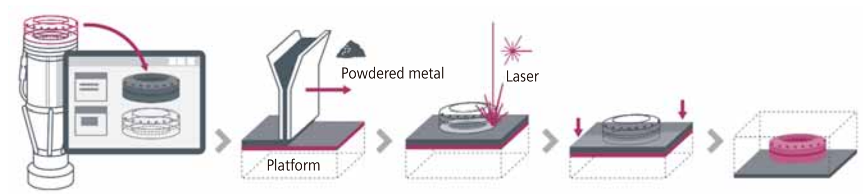
Using data obtained from scans, manufacturers create custom-fitted implants as unique items. In another sector, Siemens is now printing burner tips from powdered steel for use as replacement parts for gas turbines.

**Increasingly Efficient Machinery.** In 2013, the MIT *Technology Review* categorized additive manufacturing as one of the year's ten seminal technologies. However, AM is still too slow and expensive for industry in general. Thus, AM machines alone account for up to half of associated costs. According to the Roland Berger study, faster machinery will play the biggest role in cutting costs. "Manufacturers are now greatly increasing the machinery's efficiency," says Langefeld. "The latest generation of machines uses multiple lasers, larger build chambers, automatic

## The Basics of Additive Manufacturing

**Additive manufacturing (AM) refers to a production process in which components are produced layer by layer on the basis of digital 3D design data.**

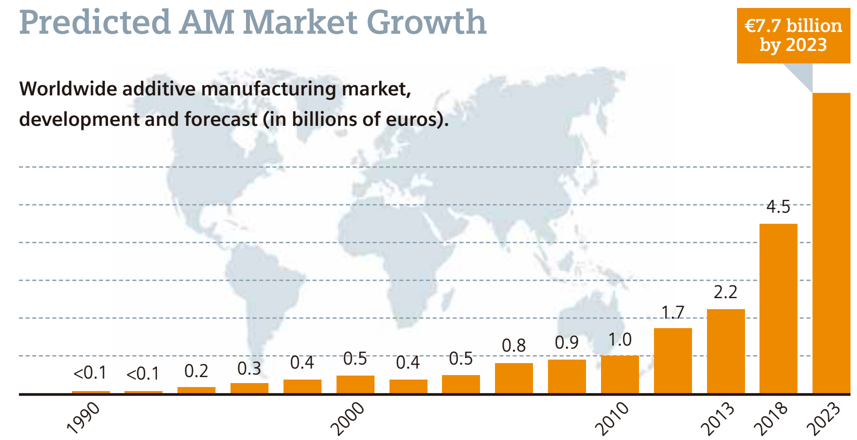
**How additive manufacturing works:**




Source: International Committee F42 for Additive Manufacturing Technologies (ASTM)

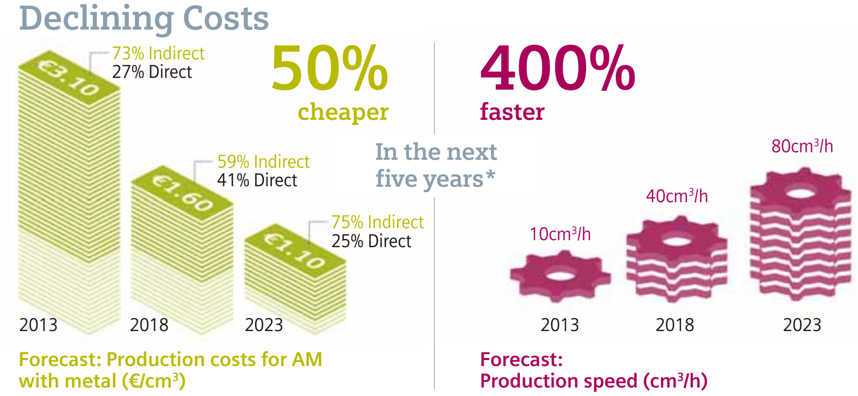
## Predicted AM Market Growth

**Worldwide additive manufacturing market, development and forecast (in billions of euros).**




Source: http://www.rolandberger.com/media/pdf/Roland_Berger_Additive_Manufacturing_20131129.pdf

## Declining Costs




*Assuming manufacturers of AM systems improve process stability and achieve a fourfold increase in the production rate.

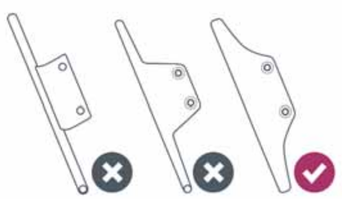
changing systems, and improved online monitoring features. Performance can be substantially increased as a result."

Powders are also a major cost factor. "Some printing machine suppliers have used the same business model as the manufacturers 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 machines had already created their own supply systems, and this led to considerable cost savings. In the study, Langefeld therefore came to the conclusion that the manufacturing costs of printed metallic products will probably be cut in half over the next five years and decline by another 30 percent in the five years after that. This assumes, however, that the current average build rate will increase eightfold over the next ten years.

## Application Areas

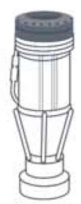
### Rapid Prototyping

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



### Production of spare parts

Using additive manufacturing reduces repair times and avoids costly warehousing. Siemens is already using the technique to repair the burner tips of small gas turbines.

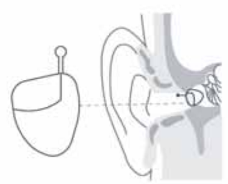


40% reduction of labor costs

90% faster repairs

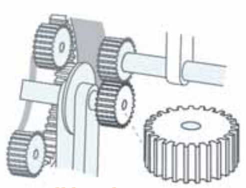
## Manufacturing End Products

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



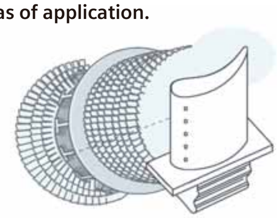
### Customized unique items

Siemens uses AM to create In-ear hearing aids, for example. Such hearing aids are individually adapted to the wearer's auditory canal.



### Small batches

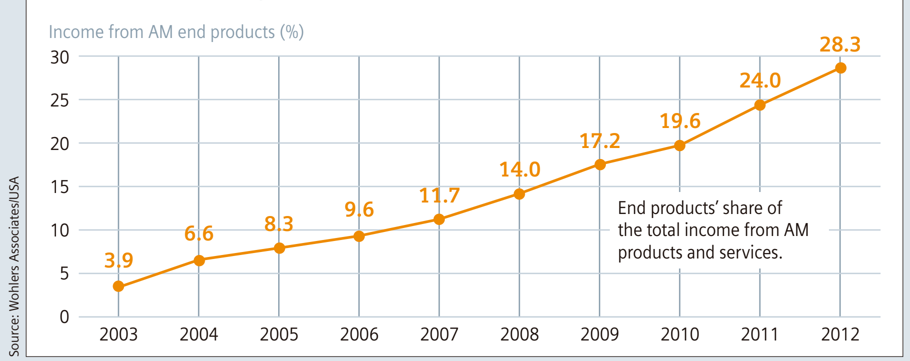
It is very costly to create molds and production lines for small batches. Such items can be produced cost-efficiently with AM.



### Very complex workpieces

AM can be used to produce very complex workpieces, which would be almost impossible to create with previously available techniques. One possible area of application is that of gas turbine blades, in which ventilation ducts could be integrated for cooling.

## AM's Growing Role in End Product Value




Source: Wohlers Associates/USA

**Heading for Faster Product Lifecycles.** However, market researchers do not expect AM to replace conventional manufacturing processes. It will instead establish itself in niche sectors involving similar parts with minimal differences. Examples include precisely tailored teeth and dental crowns, hip joints, and skull implants.

Additive manufacturing also allows companies from all industries to design products in such a way that the products can do things that conventional ones can't. That's why there is also great potential in the use of new materials. For example, AM could conceivably be used for alloys, for precious metals, and for products in which different sections are "printed" with different materials. Such products could include a material 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 produce exact and customized replacement parts on site when they are needed for individual machines or entire power plants. This would not only eliminate storage and transportation costs but also save money by preventing downtimes. For example, the all-new method for making Siemens burner tips for gas turbines reduces the repair times for certain models by around 90 percent, because the replacement part no longer has to be laboriously welded together. Instead, the burner tip is simply printed onto the body of the burner, reducing repair costs by around 30 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 cost ten times as much as a conventional item if, for example, it consistently reduces fuel demand by one percent during its entire service life. According 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*





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.

© Sierra Nevada Corporation

# From Virtual Space to Outer Space

**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.**

The world's fastest Space Utility Vehicle (SUV) will have to be able to withstand a lot. When plying its standard route between the Earth and the International Space Station (ISS), which circles the Earth at an altitude of about 250 miles, transporting people and cargo there and back, it will do more than merely travelling at over 17,000 mph (Mach 25). The *Dream Chaser*®, as it is known, will also have to withstand temperatures of more than 3,000°F. The heat generated by atmospheric friction during re-entry is enough to melt many materials , making this a very special sort of stress test.

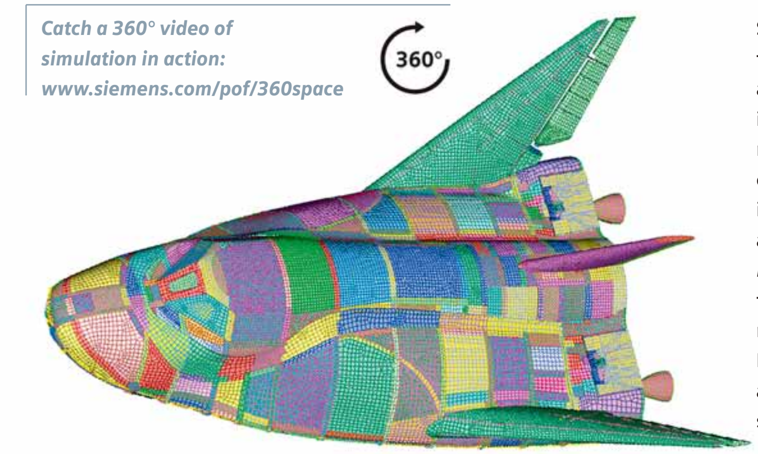
To ensure that the "Chaser" can meet such challenges, both the materials and structural engineering calculations behind it must be correct, fulfill a huge number of requirements, and work harmoniously. The vehicle itself must be the perfect shape, and simulations of its launches, flights and landings must be performed thousands of times before it is built and put into operation for the first time. Space is an extremely harsh environment and is very unforgiving of errors. The *Dream Chaser*'s development and simulation processes are ambitious, expensive and time-consuming.

© Sierra Nevada Corporation

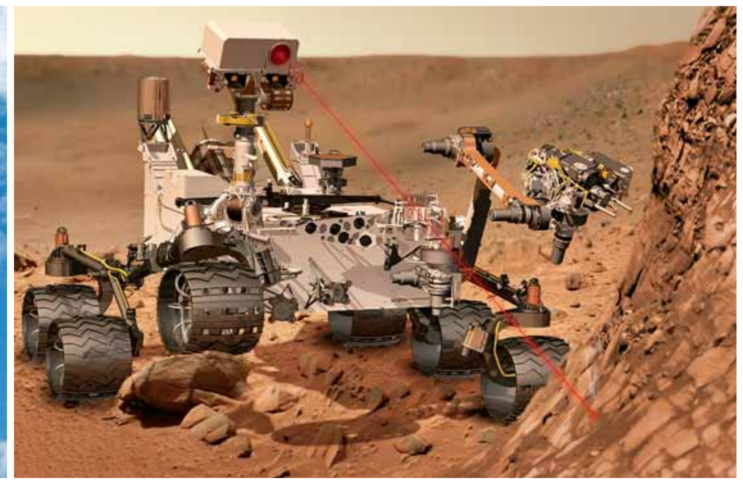
**Mission-Critical Software.** Sierra Nevada Corporation's (SNC) Space Systems, which is developing and building this reusable SUV, has gathered over 25 years of experience in space, supporting more than 420 missions and delivering 4,000 products, with no failures. More than 70 of these successful missions have been performed for NASA. In other words, it is a heavyweight with its expertise 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 advanced research – including Siemens PLM.

With its Teamcenter collaboration platform and data backbone, Siemens' PLM software provides the innovation system through which manufacturers incorporate extremely high data volumes from complex products at high speeds, analyze them and make them available to all participants. Product development teams work in a multi-CAD (computer-aided design) environment, in which different approaches must be reconciled. While it may sound simple, the role such an environment plays is critical: if an engineer

*Catch a 360° video of simulation in action: www.siemens.com/pof/360space*



**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 Ghibli sports car (p.73).**



has all of this data in one system, there is no need to spend time constantly uploading, downloading, cutting, inserting and sending. Having a single, secure source is the critical factor underlying the success of missions such as *Dream Chaser* and the Atlas V rocket from United Launch Alliance (ULA). From the PLM portfolio, SNC's Space Systems selected an integrated product design, development and manufacturing software system: The NX TM platform, which has already greatly expedited the *Dream Chaser*'s development.

"The same forces that are transforming *what* you innovate will transform *how* you innovate," says Chuck Grindstaff, CEO and president of Siemens PLM Software, who has been involved in developing software for the past 36 years. "Advanced robotics, 3D printing, knowledge automation, these are examples of where smart innovation is going. What they all have in common is that they are driven by the forces of digitization. To the extent that manufacturers leverage the digital thread to innovate, that will determine how proactive digitization will be in driving their new business opportunity."

Clearly, those who transform their operations into a digital enterprise will lead the way. And Siemens' PLM software illustrates how this can be accomplished – by helping manufacturers across industries optimize digital enterprises and realize the innovations they need for a competitive edge. The result is not just smarter products, but smarter machines making them.

**Digital Twin.** At the heart of PLM is the ability to realize products in part by the simulation of a digital twin – essentially a virtual copy of the end product in which its individual components can be inserted in different configurations and thoroughly tested – along the entire development chain. An example is the landing of the Mars Rover "Curiosity," which has been in service on the Red Planet since 2012 and was simulated thousands of times before it happened for real. Another example is American Axle. Simulations using digital twins enabled this U.S. automobile supplier to reduce road noise and vibrations and cut warranty costs by 20-30 percent per year.

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 Ghibli 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, Ghibli'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 (EWA), 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 Simatic: That is, programmable logic controllers control the manufacture of more logic controllers.

In Amberg, each product's lifecycle can be traced down to the smallest detail. Every day, about 50 million 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 preparation in the virtual space is everything. Thus, for example, leading U.S. machine tool manufacturer 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* spacecraft, 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 combinations of materials would be most appropriate for the purposes of this SUV. For example, tiles are used to protect the spacecraft against high pressure and extreme temperatures when re-entering the Earth's atmosphere. 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 realizing very individual wishes. An example from the world of sailing is 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 34th America's Cup, can simulate a range of geometries, analyze and test them, and find the right balance in terms of the demands of speed and stability. "Thanks to NX, we can test a hundred geometries at the touch of a button," reports Andy Claughton, technical director of BAR. A further benefit for sailing professionals is the huge saving of time that would previously have been devoted to bureaucratic paperwork. The rules of the America's Cup require participants to document the history of every component in terms of its constituent materials, their origin and manufacture. Teamcenter now generates this painstaking documentation digitally practically as a byproduct. Finally, the software even permits last-minute improvements: once the competition is underway, it is possible to check whether particular parts need to be replaced, removing that last grain of weight that could prove the deciding factor for victory.

"This type of digital planning represents nothing less than the future of innovation," says Grindstaff. "You need to know more than what has to be done with an innovative idea – you need to know how to deliver it. For 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 models 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 understand that they are part of a complex system 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 improving engineering throughput can create a genuine advantage on the track. Four-time FIA Formula One Constructors' World Champions Infiniti Red Bull Racing relies on the digital 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 destinations across the world.

Compared to the forces exerted on a Formula 1 driver, a trip in the *Dream Chaser* should be positively gentle. Its special construction, worked out in virtual space, will make it possible to limit acceleration forces on occupants and sensitive goods at the critical moment of re-entry into the Earth's atmosphere 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*

# Living with Autonomous Machines

**Prof. Klaus Mainzer (68), teaches philosophy of science at the Technical University of Munich (TUM). His work focuses on complexity — in nature, technology, and society. In this interview he discusses his views on the future role of autonomous machines in our lives.**

**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.

**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 workbench, transport services, the sales organization, and the dispatch unit in order to organize its own production process. The advantage here is that this production process makes it possible to manufacture customized products at mass production prices.

**Where is this development leading?**

**Mainzer:** The resulting Internet of things basically changes the way the entire infrastructure is organized. We now can have transportation systems in which vehicles communicate with one another and with traffic guidance centers, as well as smart airports and hospitals, smart grids, and even smart cities. Sociologists call these types of setup "sociotechnical systems," because human beings are one of their central components.

**In what ways might such systems change the way we live?**

**Mainzer:** They will increasingly simplify our daily lives. Technology can become successful and popular only if it corresponds to our nature, in other words to our physical and cognitive characteristics. That's why our interactions with technology should become simpler in the future. In fact, one could even say that we are entering into a symbiosis with technology. The intuitively operable smartphone is a good example of that. Today we operate it not only by means of keys, but also by speaking to it. The technology itself is moving into the background, and what remains is a user interface that corresponds to our natural interaction with our surroundings through speech, tapping, touching, and gestures. In this way we are "humanizing" our infrastructures.

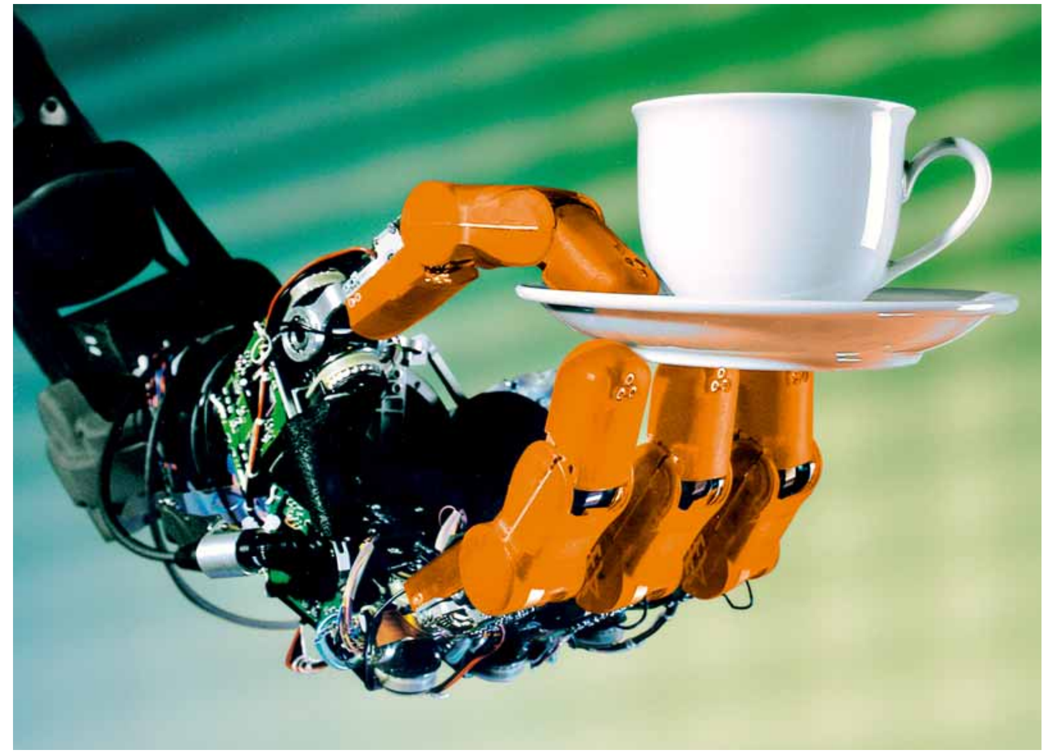
**How much autonomy should machines have?**

**Mainzer:** The autonomy of machines — meaning their degrees of freedom — will continue to increase. In the long term, this will probably be driven by the development of "neuromorphic" computer architectures that mimic the human brain. However, this will not be a case of Darwinian evolution that takes place on its own; instead, we can and should structure it. Autonomous systems are already helping us today when a vehicle performs an automatic emergency braking maneuver in order to avoid an accident. They can also play a critical role, for example in high-frequency trading on the stock exchange. There, computers have the advantage of being able to perceive the tiniest changes in fractions of a second and then take action. But this can also go wrong. We therefore need a well-grounded debate that enables us to make sure the technology doesn't get out of control.

**What's the role of machine learning in all of this?**

**Mainzer:** The ability to learn is an important prerequisite for autonomous systems so that they can cope with an increasingly complex world. Today there are sophisticated learning algorithms that are very similar to human capabilities. Intelligent traffic guidance systems can predict stop-and-go "waves" or gridlock on the basis of traffic density patterns.

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



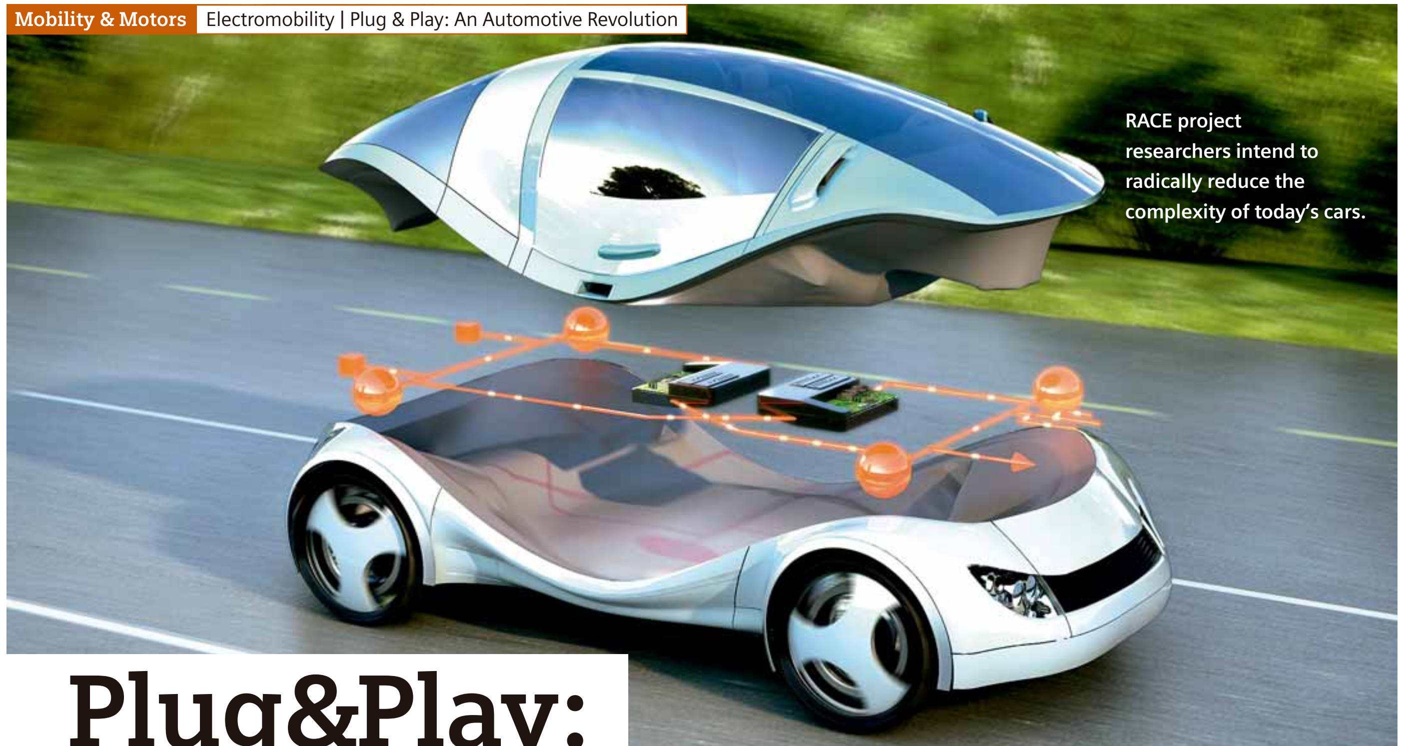
**The ability to process and draw conclusions from huge amounts of data is also transforming the role of machines in our lives, isn't it?**

**Mainzer:** There's an incredible amount of data everywhere, coming from ever-present sensors, business processes, and social networks. With the help of increasingly fast computers and smart software, you can draw correlations between these data that help you identify trends and make decisions, for example to promote business in the healthcare sector, and for traffic management. As a result, data is increasingly becoming an economic commodity. This is already almost spooky sometimes in online purchasing. For example, Amazon uses its gigantic amounts of data and its smart software to predict its customers' purchasing behavior. The company stockpiles products even before the customer has ordered them. Or think of 3D printers. If one day we have machines that can use this technique to make very complex products such as automobiles cheaply, then the only important thing will be the data that's fed into the printer. The data will then be the actual thing that is valuable.

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

**Klaus 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*



RACE project researchers intend to radically reduce the complexity of today's cars.

# Plug&Play: The Drive for Digital Cars

**RACE, a research consortium headed by Siemens, plans to replace the jumble of electronic systems in cars with a kind of operating system that will digitize steering, breaking, and acceleration. The first vehicle based on this new architecture is the StreetScooter electric van.**

Cornel Klein, a Siemens software engineer, steers a compact yellow van through a city. After a left turn, he proceeds carefully through a large puddle. One might think this is a simple everyday situation, but it's not. The vehicle Klein is steering is actually one meter above the ground, and the van's tires are spinning in midair. As a result, the whirring electric motors aren't moving the vehicle the slightest bit forward.

The van is mounted on a test rig in Siemens Corporate Technology's research center in Munich. In front of the windshield, Klein sees a city projected on a screen. When he steers or accelerates, the external motors connected to the van's axles respond, thus helping to simulate a variety of driving situations. The van, which was built by the German electric vehicle manufacturer StreetScooter, is a key component of the Robust and Reliable Automotive Computing Environment for Future eCars (RACE) research project, which was launched in 2012 and is headed by Siemens. Funded by Germany's Federal Ministry for Economic Affairs and Energy, the project has eight partner organizations, including Siemens, StreetScooter, the fortiss Institute at the Technical University of Munich, and RWTH Aachen University. The aim is to revolutionize vehicle technology by creating a completely digital car.

RACE aims to replace traditional decentralized electronics with an automotive operating system on which new functions can be installed like apps on smartphones. Steering, acceleration, and braking systems would no longer be controlled mechanically but by RACE-controlled motors. "Remember the memory typewriters of the 1980s?" asks Klein, who manages the RACE project. "The PC swept that technology from the market. RACE might trigger a similar change."

**The Plug-and-Play Car.** Creating an overarching 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 technicians have to install new cables and update the display systems and existing electronics.

RACE, by contrast, is a computer architecture that combines the strengths of the centralized and decentralized approaches to controlling 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 standard control unit with a RACE control unit that regulates the drive system and the energy recovery process. The new software platform has not yet been completed, but it demonstrates that this technology can be integrated into vehicles equipped with a traditional system architecture. That's why the electric StreetScooter has been named "Evolution" 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 vehicles 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 more efficient battery control system or an application that intensifies the stereo system's bass — according to the plug-and-play principle.

The platform can also be retrofitted with sensors for features such as reversing cameras and with actuators for systems such as motors, lamps, and displays. These systems would be connected to RACE computers via a standardized bus system. Vehicles could thus be updated quickly and inexpensively.

Vehicle development times would be shortened as well. Achim Kampker, CEO of StreetScooter and a professor at RWTH Aachen University, says, "We believe that if you combine our vehicles' modular design with RACE technology, you could halve the development time for a new vehicle model while greatly reducing development costs."

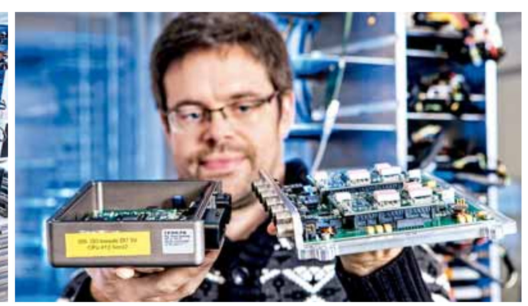
**Reinventing the Automobile.** RACE researchers are using an unusual research vehicle — the Roding Roadster Electric — to demonstrate what the future might look like. The vehicle is an experimental electric sports car that is now parked next to the Siemens test rig. In this car, the RACE operating system unifies the electronics and eliminates all of the mechanical systems between the steering wheel, brake pedal, and gas pedal on the one hand, and the motor and wheels on the other. This setup is known as "drive-by-wire" and is analogous to the fly-by-wire computer control system used in airplanes. Pressure sensors in the brake and gas pedals send data to a computer that forwards appropriate digital commands to the brakes and the motor. The steering wheel controls the wheels not via the steering column but through an actuator that is operated by means of digital signals. The vehicle's motor is incorporated directly into the wheels via a wheel-hub drive in the rear axle, and the car's battery pack is wirelessly recharged from a charging plate on the garage floor. No current mass-production vehicle boasts the Roding's combination of innovations, so it's no surprise that it has been called the "Revolution." However, the Roding won't be mass-produced — it's merely a test platform for RACE technology.

## We believe we can cut the development time for a new vehicle model in half.

**A Firewall for Cars.** What would happen if a hacker used an infected update to freeze the onboard computer or suddenly order an emergency stop? The RACE project's software security expert, Prof. Manfred Broy from the Technical University of Munich, says, "In principle, we already know how to design secure updates. You need to install firewalls, introduce clear security requirements, and have a general security concept for the onboard systems."

Vehicles are becoming increasingly digitized, and RACE technology is being seamlessly integrated into innovations such as autonomous driving and the "vehicle Internet," which facilitates car-to-car and car-to-infrastructure communication. RACE technology can also help to simplify the control systems of complex machines such as rail vehicles.

But for now, work is focusing on the continued integration of RACE architecture into the StreetScooter, with fewer computers and drive-by-wire technology. "If everything goes as planned, the first RACE-controlled StreetScooter vehicles will roll off the line in 2016," says Klein. *Hubertus Breuer*



Left: Comparing a RACE vehicle with the complexity of today's mid-range cars. Center and right: Siemens researchers test software functions on the terminal control instruments integrated into a RACE vehicle.

Left: A key step in equipping a vehicle with RACE technology is commissioning its powertrain. Right: A RACE vehicle's driving behavior is tested on a Siemens test rig in Munich.

*A PoF Digital video illustrates the concept and functionality of RACE: www.siemens.com/pof/race*

In the near future, Wuhan's police officers will be able to use a smartphone app to manually optimize traffic light timing.

# 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.**

It'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. Hanzhong Zhang, the traffic policemen who is responsible for this intersection, uses his walki-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. Zhang 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 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 400 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.

**Authority Versus Automatic Systems.** Automatic 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 policemen 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 ends. 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 Engines!** 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.

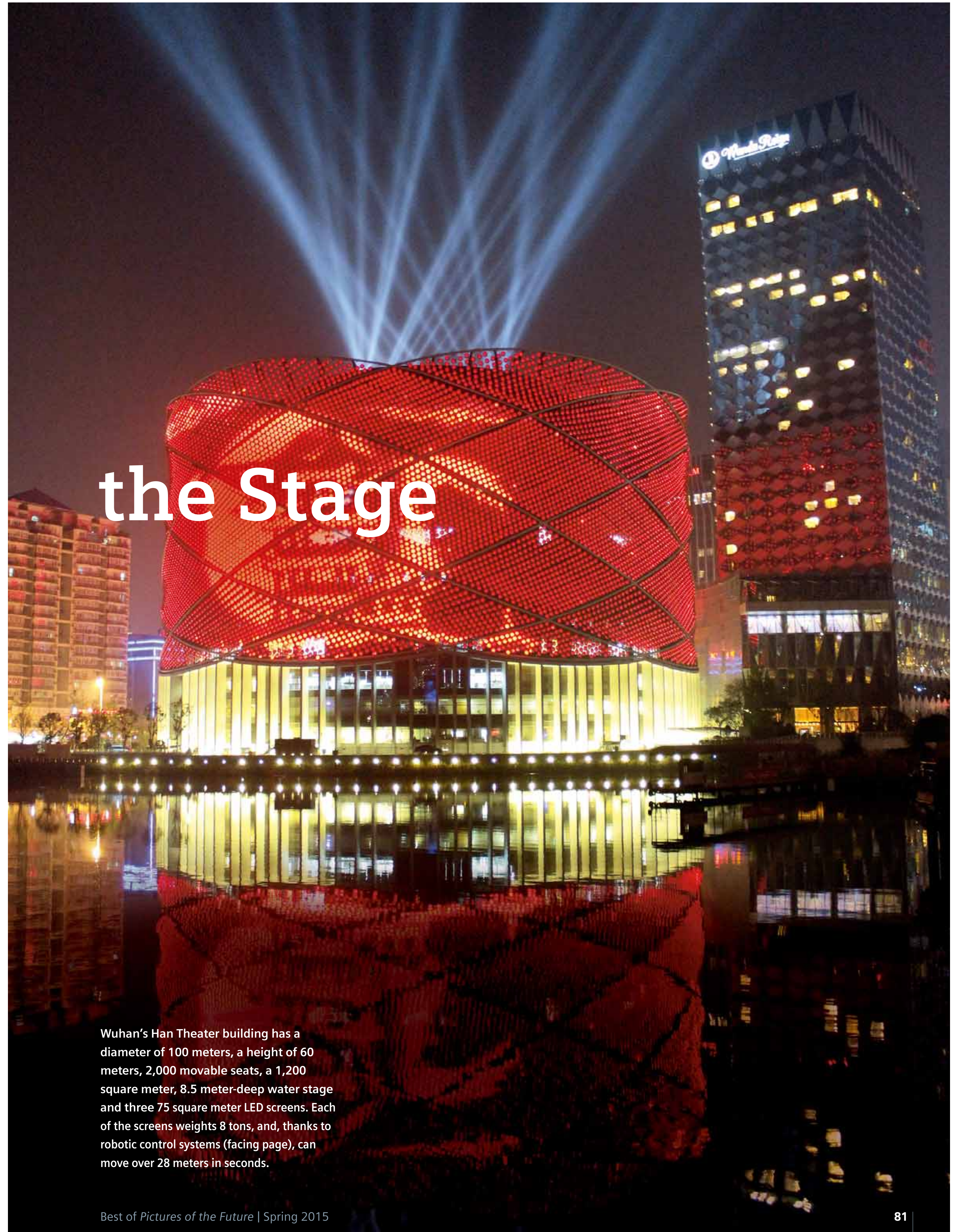
On the drive back from the Innovation Center, Technical Manager Qiu stops his car next to a traffic light controller that bears the name of a competing company. These controllers are cheaper than the ones from Siemens, but they aren't networked; as a result, they're not suitable for managing the traffic 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. Automatic systems 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*

**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.**

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*."

# Siemens Takes the Stage



Wuhan's Han Theater building has a diameter of 100 meters, a height of 60 meters, 2,000 movable seats, a 1,200 square meter, 8.5 meter-deep water stage and three 75 square meter LED screens. Each of the screens weights 8 tons, and, thanks to robotic control systems (facing page), can move over 28 meters in seconds.

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 outdo 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.

**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 almost as 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.

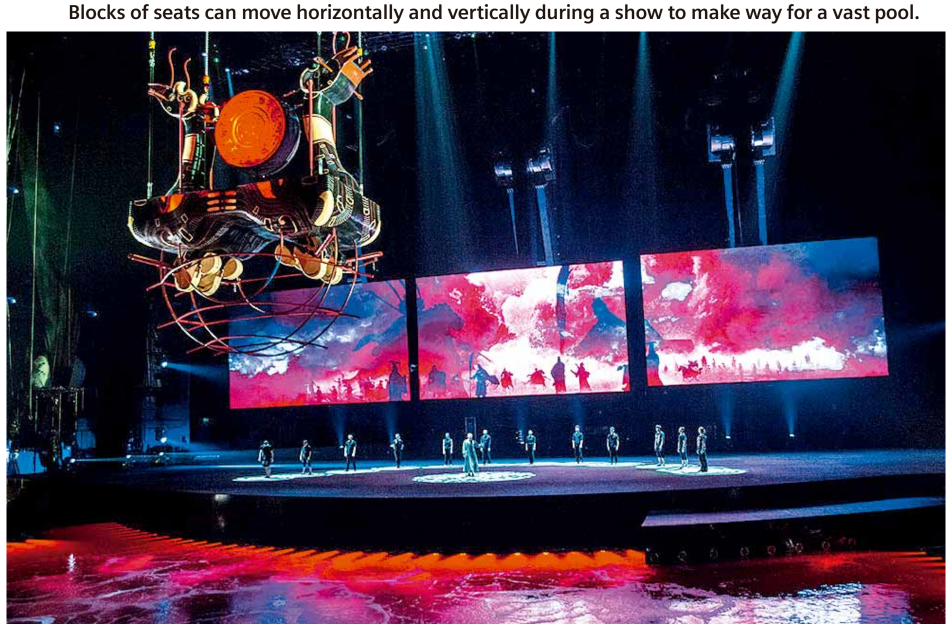
Instead of huge hands, the screens are moved by three robotic arms — the largest ever used for a stage show. These arms are similar to the industrial robots used to weld metal sheets in the automotive sector, for example. The main difference is that the Han arms are much bigger, because each screen weighs 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 predetermined choreography or the screens would collide. To ensure such precision, the control system has to coordinate six joints, 12 motors, and 14 axles on each robot — for a total of 42 axles. "This is achieved by Siemens Motion Control," says Renrong Hu, Chief Engineer of Stage Control Systems at Wanda Group, which is the company that built the Han Show Theater and produced the event. "Although we looked at various products, only Siemens offered a precise multi-axle 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

## 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.

would work in practice," admits Hu, adding: "Siemens has really taken a big load off our minds."

Hu was particularly impressed by the work done by the company's technicians. To complete the robots' assembly, the technicians had to climb up a 50-meter-high metal scaffold, which they did with "moist hands and feet," as Siemens engineer Jiaxing Xi admits.

It gave Xi and his colleagues a feeling for how much the performers' lives depend on the care with which the technicians do their work. Among other things, the installation controls and operates a trapeze act involving dozens of acrobats who perform heart-stopping flying stunts with 60 single point cantilevers and 12 rail cars that are suspended above the audience from the ceiling.

**Movable Seats.** The audience also moves around during the show. The spectators first face the stage. Later in the show, the galleries split and arrange themselves in blocks around the pool, which was up to then hidden beneath the galleries. The rows of seats rotate and move horizontally and vertically during the show. The seats are also directed by SIMOTION D435 motion controllers and driven by hydraulic cylinders with a range of six meters. This could also be a new record, because the theater has the biggest sections of movable seating ever made for a building interior.

Although the other Siemens technology contained in the theater is less spectacular, it is just as important. Several components are contained in the building's low-voltage supply system, while programmable logic controls ensure the safety of performers and the audience. Siemens also supplied the building control system, as well as the building's PROFINET data transmission infrastructure.

The *Han Show* has been Siemens' baptism of fire for stage production equipment in China. Renrong Hu suggests that the cooperation between Wanda and Siemens in Wuhan won't be the last of its kind. "We are planning to build additional world-class theaters elsewhere in China," he says. "And we are looking forward to continuing our collaboration with Siemens." *Bernd Müller*



**Pictures** of the Future
The Magazine for Research and Innovation



# Up-To-The-Minute Multimedia

**The New Online Magazine *Pictures of the Future***

**Twice a year since 2001,** Siemens' *Pictures of the Future* magazine has reported on the key trends shaping our future, as well as the most exciting innovations and research developments. But readers' habits are changing. Newspapers and magazines are being read less and less in paper form, and more and more on tablets, PCs, and smartphones.

**Accordingly,** as of October 2014, we transformed *Pictures of the Future* (PoF) into a high-quality online magazine. As a result, the magazine is now more up-to-the-date, new articles are published several times a week, and the publication is more multimedia-based. Sections of text are supplemented with videos, animated infographics, image galleries, and interactive 360-degree features. In addition, the magazine is being continually expanded in line with its readers' wishes and its motto is "Digital First." *Pictures of the Future Digital* is now the basis for other products, both in print and, in the future, also as tablet and smartphone versions. In addition, its contents are distributed through many other channels ranging from social media to internal and external media.

**As is usual in online magazines,** *PoF Digital* is subdivided into sections. But rather than being called Business, Politics, or Sports, their headings are "Industry & Automation," "Digitalization & Software," "Energy & Efficiency," "Health & Well-being," and so on. Readers can subscribe to some or all of these sections, depending on their interests. Added value is offered by dossiers dealing with themes such as "From Big Data to Smart Data," "Additive Manufacturing," and "Smart Grids and Energy Storage." Here you can find information about key issues in the form of scenarios, trend articles, reports, interviews, and business analyses.

**Our aim is to give our readers** an expert and comprehensive overview of each issue that is nonetheless as concise as possible. For example, after reading the dossier "Additive Manufacturing," you will know how additive manufacturing works in an industrial company, what trends can be observed on the market, and what the status of this development is at Siemens. Today, *PoF Digital* includes 22 dossiers — and some more will be added every year. In view of these developments, we expect that, in our increasingly digital future, *Pictures of the Future* will continue to be the leading medium through which Siemens communicates about innovation. Join us as we explore exciting new technology applications and rapidly evolving fields of research. Join us in *PoF Digital* at: *www.siemens.com/pof*.

Ulrich Eberl, Sebastian Webel, Arthur F. Pease

PS: As of this issue, after 14 years as founder and Editor-in-Chief of *Pictures of the Future*, I bid you farewell. Sebastian Webel, Arthur F. Pease, and the entire PoF team will continue to ensure the quality of our innovation magazine. To you, dear readers, I wish all the best for the future! Yours truly, *Ulrich Eberl*

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