THE THYSSENKRUPP TECHNOLOGY MAGAZINE
02 2014

techforum

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SMART ENERGY SYSTEMS

RESEARCH FOR THE ENERGY OF THE FUTURE

Production, storage, distribution: the new technologies we need for the switch to renewables

CO_2 AS A RAW MATERIAL

How this greenhouse gas can be used as a basic material for chemical products

LOAD MUST FOLLOW GENERATION!

How to keep networks stable and the cost of the switch to renewables manageable

BATTERIES OR HYDROGEN?

How to store renewably generated energy

ThyssenKrupp

The human race may emit a maximum of some

1,000

billion tons of CO_2 if global warming is to be restricted to no more than two degrees Celsius.

→ SAYS **HANS JOACHIM SCHELLNHUBER** IN AN INTERVIEW ON *PAGE 10*

GERMANY ALONE EMITS SOME

900

MILLION METRIC TONS OF CARBON DIOXIDE EVERY YEAR.

→ MORE ON THIS FROM *PAGE 14*

As renewable energy continues to expand, global demand for energy storage devices is set to rise to

330
gigawatts

by 2030.

→ FIND OUT WHICH STORAGE DEVICES **THYSSENKRUPP** IS DEVELOPING ON *PAGE 16*

→ Germany has set itself the target of generating **30%** of its energy from renewable sources by 2030.

THE EU WANTS TO CUT CO_2 EMISSIONS BY 40% BY 2030 COMPARED WITH 1990.

→ FIND OUT WHAT **THYSSENKRUPP** IS DOING TO MAKE THIS HAPPEN ON *PAGE 24*

At a pressure of **200 bar** hydrogen stores more than **50 times** as much energy as compressed air.

→ READ MORE ABOUT THIS ON *PAGE 16*

GERMANY COULD SAVE SOME

€5.6

BILLION EVERY YEAR THROUGH MORE EFFICIENT ELECTRICITY MANAGEMENT.

→ FIND OUT HOW THAT IS POSSIBLE ON *PAGE 20*

Dear readers,

Technology magazines at ThyssenKrupp form a tradition that dates back more than 90 years: the "Kruppsche Monatshefte" (Krupp Monthly Journal) first appeared in 1920, and since then we have published titles such as "Technische und wissenschaftliche Berichte" (Technical and Scientific Reports), "Berichte aus Forschung und Entwicklung" (Reports on Research and Development), and now the ThyssenKrupp **techforum**. Over this time, we have not merely repeatedly changed the visual appearance – we have also constantly adapted the language and style of reporting, in order to remain right up to date. One thing has never changed, however: the paramount importance of research and innovation for ThyssenKrupp. Engineering skill is and remains part of our Group's DNA.

The latest edition of **techforum** is the result of a further adjustment. We have kept the magazine's broad range of subject matter, but given it a clearer structure. Well-informed coverage of those subjects remains a distinctive feature of techforum, but we have made it more reader-friendly. Ultimately, this new visual appearance brings it into line with other modern magazines.

The systematic expansion of our innovative strength is one of the most important components in our company's strategic further development. ThyssenKrupp stands for sustainable products, sustainably made. In this way, we want to put our customers in a position to conserve raw materials and energy and to operate in resource-friendly material cycles.

Smart energy is one example of this. In the pieces on our cover theme you can read about how our researchers and developers are working on solutions which will be decisive for the success of the switch to renewables. These include turning CO_2 into valuable basic chemicals, storing renewable energies, and making industrial production processes more flexible so as to adapt them to the fluctuating supply of wind and solar power.

Another key area is the "InCar plus" project, where we have developed 40 new solutions for sustainable automobile construction. "InCar plus" represents more efficiency in cost, weight, and functionality. We have demonstrated its environmental benefits in holistic life-cycle analyses. The latest **techforum** also reports on new developments in our Elevator and Steel Europe business areas.

I hope you will enjoy the new ThyssenKrupp **techforum**. We look forward to your views and comments sent to contact.techforum@thyssenkrupp.com!

Yours,

DR. HEINRICH HIESINGER,
CHAIRMAN OF THE EXECUTIVE BOARD

“SHAPE THIS TRANSITION WITH CREATIVITY”

ON THE WAY TO A SUSTAINABLE ECONOMY

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Economical PROCESS

New electrolysis technology lowers energy consumption by 30 percent.

Innovation boosts efficiency: Oxygen depolarized cathodes for the production of chlorine and sodium hydroxide solution.

ThyssenKrupp has together with UHDENORA and Bayer developed a new process for the production of chlorine and sodium hydroxide solution. Plants with the new oxygen depolarized cathodes (ODCs) consume 30 percent less energy compared with the conventional membrane process. The new technique incorporates know-how from UHDENORA, ThyssenKrupp Industrial Solutions, Bayer MaterialScience, and Industrie DeNora.

Chlorine is one of the key chemicals in the chemical industry: two-thirds of all chemical products are manufactured using it. If all chlorine producers in Germany were to switch over to the new technology, the country's energy consumption could be reduced by one percent. Sodium hydroxide solution is used chiefly in the aluminum and mining industries as well as in the production of detergents, pulp, and paper.

The first plant with the new ODC technology and an annual capacity of 80,000 metric tons of sodium hydroxide solution is being built by the BEFAR Group, a chemical enterprise, in Binzhou in China. The new electrolysis technique will reduce CO_2 emissions from the plant by up to 35,000 metric tons compared with facilities using the traditional membrane process. With their ODC technology ThyssenKrupp, UHDENORA, and Bayer have also reached the final of the German Industry Innovation Prize.

Test tower for elevators

Rottweil is gaining a new landmark. The town's medieval and fortified towers will soon be joined by one of Germany's tallest buildings: ThyssenKrupp Elevator's new 244-meter-high test tower. Its function is to test out and certify high-speed elevators. The test shafts are designed for elevator cab speeds of up to 18 meters per second – around twice as fast as Usain Bolt's record-breaking 100-meter sprint. The tower designed by architect Helmut Jahn will also feature, at 232 meters, Germany's highest visitor platform.

Expanded cooperation with RWTH Aachen University

ThyssenKrupp and RWTH Aachen University have been working together intensively for many years – in particular the Steel Europe business area maintains close contacts with the renowned educational establishment. At a joint "R&D Forum" in early June the partners discussed future strategic cooperation projects: Professors from RWTH Aachen University together with representatives from ThyssenKrupp identified in the "Automotive", "Plant Chemical", "Materials", and "Industry 4.0" workshops key future topics that are to be jointly developed further. The collaboration with RWTH Aachen University is part of an extensive program of cooperation between ThyssenKrupp and leading higher education institutions across the globe.

Equipment engineering for BMW i3 batteries

ThyssenKrupp has been championing the advancement of equipment engineering for the manufacture of lithium ion cells and battery systems for years – including at its own technical center close to Chemnitz. The company's process innovations have now also entered production: ThyssenKrupp System Engineering has planned and established the production plant for the batteries destined for the new BMW i3 electric vehicle. Here finished battery cells are processed into modules and tailor-made battery systems. The new vehicle also seems to be going down well with customers: in the first six months of 2014 alone, BMW sold 5,400 i3 models.

ThyssenKrupp is developing efficient processes for building battery cells and systems at its **technical center near Chemnitz**.

Speeding things up

One walkway, two speeds: ThyssenKrupp is developing a walkway that combines smooth speed changes and the highest safety requirements for passenger transportation. Commuters from outlying districts can use it to reach their next metro station quickly and without waiting periods, which dispenses with the need for unprofitable shuttle buses. At airports, this revolutionary technology saves passengers two-thirds of their time – which they can then spend in the stores on site.

0.65 meters per sec.

For 270 meters, passengers now need only 140 seconds instead of 415 – a saving of 66 percent.

Two meters per second

In the middle section, the pallet band accelerates smoothly to two meters per second.

0.65 meters per second

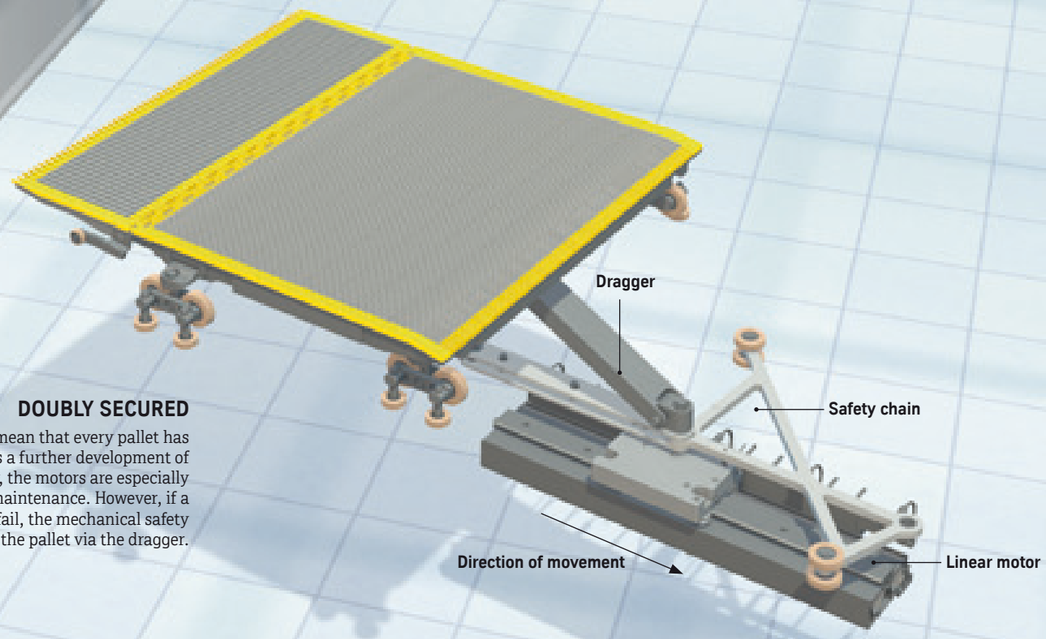
The entrance speed is the same as that for conventional walkways. Even with luggage, passengers can step onto the band in comfort.

SPEED CHANGE

Each aluminum pallet consists of two parts. At the entrance, they are laid closely one over the other. As the speed increases, they push apart, before coming together again near the end. This interaction ensures smooth speed changes with constantly high and safe traveling comfort.

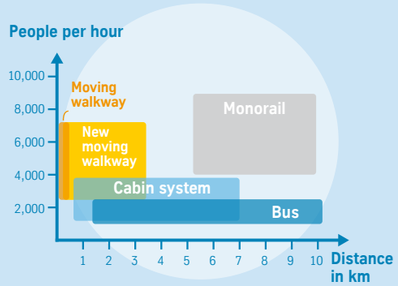
IN SYNC WITH SENSORS

The pallet band and handrail are two separate systems – but they are precisely in sync. Sensors focus constantly on the position of the individual grips and pallets and make sure that passengers always have the feeling that these are moving at the same speed.



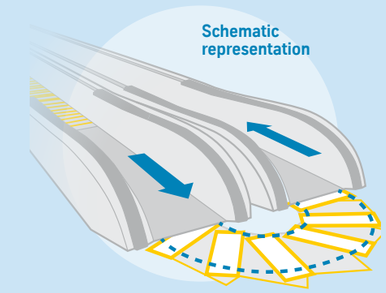
DOUBLY SECURED

The linear motors mean that every pallet has its own drive unit. As a further development of Transrapid technology, the motors are especially low-vibration and low-maintenance. However, if a motor does occasionally fail, the mechanical safety chain engages and pulls the pallet via the dragger.



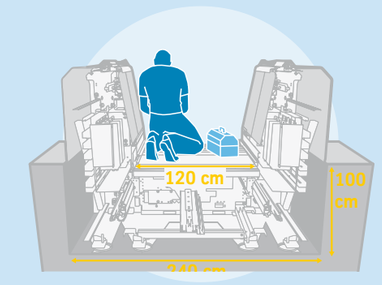
TRANSPORTATION OF THE FUTURE

At 7,300 people per hour, the moving walkway can transport more travelers than fully automated cabin systems, for example – with no waiting periods at all. At large airports, passengers can get more quickly from A to B, without needing buses or skytrains. In towns, the walkway can take the place of unprofitable bus connections, and trade show operators can use it both indoors and outdoors.



CIRCUITS SAVE SPACE

It looks like an ordinary walkway to the user, but in fact it forms a circuit. The pallets return via the opposite lane. The bends are invisible, below the floor surface. This is how the the new walkway achieves its small construction depth of only one meter – similar to conventional walkways. Also, the customer has the option of using two walkways for the price of one and a half.



SAFETY FIRST

There have already been attempts to establish walkways with different speeds. However, with the exception of the ThyssenKrupp TurboTrack at Pearson International Airport in Toronto, none of them has operated trouble-free. With the new moving walkway the engineers have again increased safety and ease of maintenance. All relevant components can now be reached via the pallet band – this saves operating costs.

TEXT: LENA BULCZAK
INFOGRAPHIC: NIKO WILKESMANN

Sustainability – an engine of innovation

TEXT: JOST BURGER
PHOTOS BY: GÖTZ SCHLESER

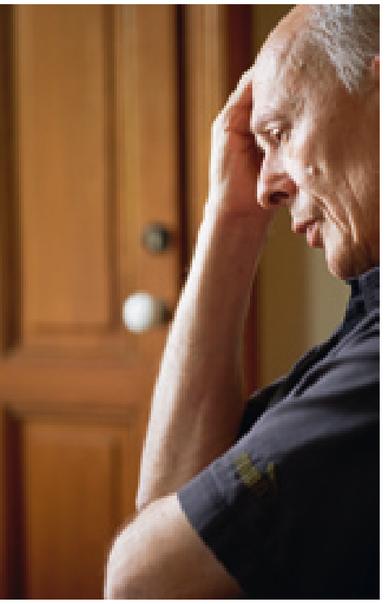
Environmentalist meets technology chief: Professor Hans Joachim Schellnhuber and Dr. Reinhold Achatz discuss the 21st century economy. They are agreed that sustainable companies have the better economic prospects in the long term.

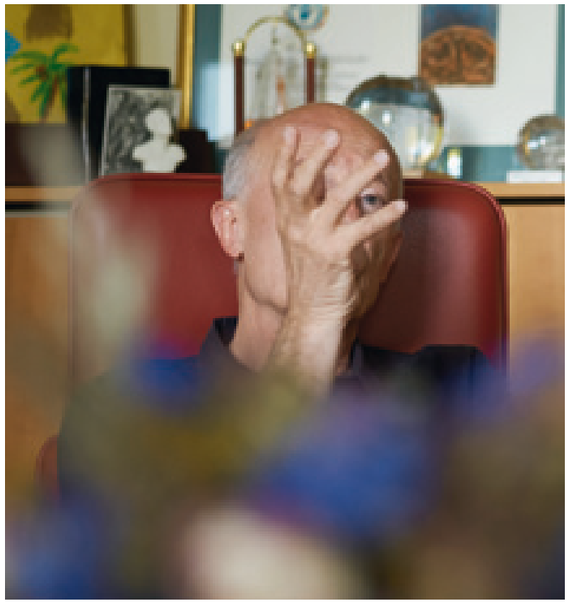
A hot day at the height of summer. In Potsdam the air is shimmering. Over the city, on the Telegraphenberg hill, a slight breeze is blowing at least, cooling the visitor as he makes his way between bright brick buildings to the heart of one of Germany's oldest scientific institutions. In the mid-nineteenth century the Prussian king ordered the building of observatories here, and later on the hill became a station in the semaphore system between Berlin and Koblenz. The Einstein Tower recalls Albert Einstein, who worked here. One of the oldest continuously operating measuring stations has its home here. Today a number of institutions continue to research and operate on the Telegraphenberg, including the Potsdam Institute for Climate Impact Research (PIK) – making this an ideal location for a discussion between Professor Hans Joachim Schellnhuber, Director of the PIK and one of the world's most renowned climatologists, and Dr. Reinhold Achatz, Chief Technology Officer at ThyssenKrupp AG, on the opportunities which sustainability offers the business sector.

techforum: What opportunities does the linking of sustainability and business offer?

Prof. Hans Joachim Schellnhuber: Firstly, sustainability means offering future generations the option of being at least as well off as we ourselves. Everyone can really subscribe to that. From the perspective of science, however, specific boundaries and limits need to be observed to achieve this: The raw materials on our planet are finite, after all. These boundaries should also provide guidance for the business sector – on how it can function and develop. I am sure that those who recognize our planet's limits in good time will also do better business going forward. If I can recognize what is necessary and turn it into opportunities, then as a company I have interpreted sustainability correctly. ⇢

Two visionaries above the roofs of Potsdam: Beside the observatory on top of his institute's building, Professor Hans Joachim Schellnhuber (left) and Dr. Reinhold Achatz cast their eye over the future of the economy





Dr. Reinhold Achatz: We also say that if our products and solutions are not sustainable, the company will not survive in the long term. On the topic of raw materials, companies such as ThyssenKrupp are relying increasingly on circulatory processes with multiple use and recycling.

Schellnhuber: A form of development is certainly needed that really thinks processes through. For instance, if I think about cycles, then alongside the sources and the raw materials I also have to consider the sinks, of course. Everything points in particular to the fact that we have only a finite carbon budget: our whole civilization may emit a maximum of some 1,000 billion metric tons of CO_2 if we wish to restrict global warming to no more than two degrees Celsius. The question therefore needs to be asked: how quickly can major emitters such as ThyssenKrupp reduce their CO_2 emissions?

“BIGGER PROFITS THROUGH A FORWARD-LOOKING, SUSTAINABLE FOCUS”

HANS JOACHIM SCHELLNHUBER

Achatz: We look at the entire life cycle of our products, equipment, and services, including from the angle of what can be recycled from the intermediate stages and from the finished product. If a company does that, this is also very attractive from the point of view of economic viability. Here is an example of our activities: At the Leuna site we are working on creating from renewable – and also inedible – raw materials the basis for biodegradable plastics, which decompose by themselves in a relatively short period into natural substances. In addition, we have the issue of energy efficiency, which we as ThyssenKrupp are also promoting very intensively. Energy efficiency is reducing our electricity consumption and CO_2 emissions, firstly. At the same time, energy efficiency measures are increasing total efficiency in many processes, cutting costs in turn: And there we have again the link between sustainability and cost-effectiveness.

Schellnhuber: For an advanced economy in particular, it is a question of whether you see yourself as part of a race to the bottom or a race to the top. Again and again we hear the argument: if we factor too much sustainability into our production costs, it is our much more polluting rivals who gain. But this is the question we should be putting: Would I not rather be part of the economy of tomorrow, even if this means that initially and here and now I have to sacrifice some of my cost-effectiveness? As part of the new economy I will make much bigger profits sometime – because thanks to my forward-looking, sustainable focus I will still be around long after the others have disappeared from the market.

Achatz: The exciting aspect is the transition. How do I move from the present world to the future world? How we shape this transition is a question of creativity. From my perspective, it is about creating new systemic relationships and optimizing these systems holistically. We are trying to do this right now with the PLANCK project. Our idea – together with the Max Planck Society and other partners from the chemical and energy sectors – is to view a steel mill as part of a chemical chain. A steelworks produces both steel and steel mill gases that contain CO_2, CO and hydrogen, methane or even nitrogen. These are raw materials, including the CO_2! Not in the steel sector, of course. But from hydrogen and nitrogen you can produce ammonia and from that fertilizers, for example. The production of artificial fuels is also possible. For that we need more hydrogen than is actually generated from steel production. It could be produced through electrolysis, for which we plan to obtain the required electricity from renewable sources. With the technologies we are developing with PLANCK, in principle all the CO_2 from steel mill gases could be converted.

Schellnhuber: Such approaches are indeed fascinating. System solutions are very exciting and have a lot of potential.

techforum: Are you already registering a response on the capital markets?

Achatz: At the last shareholders’ meeting several potential innovations were mentioned, one of which was the recycling of steel mill gases, with biodegradable plastics being another. The number of investors who are interested in and guided by sustainability criteria is growing and growing.

Schellnhuber: There is an increasing number of investors who just like civil society are becoming more and more interested in “green” criteria. At the same time, any ordinary bank customer can, of course, ask: Where are you actually investing my money? Sooner or later it will enhance the reputation of companies in the eyes of private investors if they invest and operate sustainably. This is not a top-down but an inside-out process: Does a company see itself as part of the problem or part of the solution?

Achatz: I think the process is already more advanced than you are describing. We have had sustainability reporting at ThyssenKrupp as an essential part of our overall reporting system for a long time now. And there is also demand for this.

techforum: Where do the markets for sustainable solutions lie right now or in the near future?

Achatz: I have formulated a sentence for us: We must produce sustainable solutions for our customers sustainably. Our customers will demand sustainability in products, services, and solutions.

Schellnhuber: To some degree the sustainable markets still need to be created as well: Potential customers must perhaps first be convinced that they need a thing that has been of no importance to them hitherto. This is also pioneering work – look at Berlin, for instance, which is seeking to develop into a climate-neutral city by 2050, leaving a carbon-based energy industry behind.

techforum: Let us return to the topic of reduction: ThyssenKrupp has an extensive energy efficiency program…

Achatz: Yes, that is right. We are in the process of setting targets for 2020.

Schellnhuber: And what will they be?

Achatz: Within the program we studied individual companies and facilities across the Group over a six-month period. In a further step we have defined the potential savings in the technology groups specified. From this we will determine an efficiently measurable figure for the whole Group. This figure will then form the basis of informed management decision-making.

techforum: What about the political framework in Germany?

Achatz: We are talking here about investment decisions with a horizon of eight or ten years. At the present time it is unclear in very many areas what conditions we will be living under in a few years’ time. We therefore need clear commitments from the government.

Schellnhuber: The EU is seeking to cut CO_2 emissions by 40 percent by the year 2030 compared with the 1990 level, which for Germany will probably mean 50 percent. This is the message being sent out. In my view, the drive for decarbonization will then proceed very quickly. Industrial history teaches us that you simply cannot operate two different systems in parallel in the long term.

Achatz: Where decarbonization does not mean using no carbon anymore, but recycling it.

Schellnhuber: That can be one approach. It is important to complete the withdrawal from emissions by the middle of the century. Let me reiterate that time is actually running out as far as our climate is concerned. If we do not get to grips with climate change issues, there will be no sustainable management on this planet either. I am very familiar with the debates going on in the business community: they are happy to join in provided that everyone worldwide is subject to the same competitive conditions. But that cannot and will never happen. Countries such as Germany can set a good example, nonetheless, even if other countries still have weaker regulations for now.

“WE CAN GENERATE MORE BUSINESS IF WE HAVE SUSTAINABLE OFFERINGS”

REINHOLD ACHATZ

Achatz: Let us not forget one thing: ThyssenKrupp operates not only in Germany, but also in the USA, in China, and South America. We want our sustainability technologies to gain ground across the entire world. Duisburg is not the only place where ThyssenKrupp has steel mills, for example. We see the recycling of steel mill gases as a business opportunity for the global steel industry. This also serves as an example of how we can generate more business if we have sustainable offerings.

CO_2 as a raw material

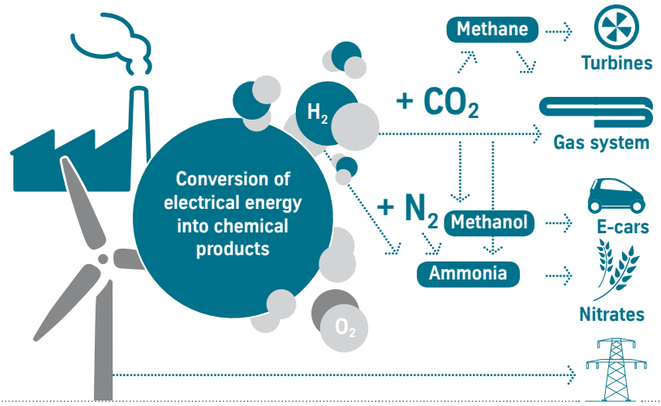
ThyssenKrupp is launching the first cross-industry initiative to utilize carbon dioxide from steel mill gases. Its aim is to exploit steel mill gases as the starting material in the production of chemicals. The PLANCK project is contributing not only to climate protection but also to the success of the switch to sustainable energy.

Carbon dioxide has a terrible image. Discharged into the atmosphere in large volumes, this greenhouse gas is fueling global warming and becoming a climate killer. In Germany alone industrial chimneys, cars, and households emit some 900 million metric tons of CO_2 every year. Yet carbon dioxide is far from being just something that harms the climate – the gas can also serve as a valuable raw material in the chemical industry.

The idea for the project came to ThyssenKrupp's Chief Technology Officer Reinhold Achatz during a lecture. His colleagues at ThyssenKrupp Process Technologies had presented the fundamental possibility of synthesizing ammonia and methanol from steel mill gases – ammonia is used in the production of fertilizers and methanol in fuel production, among other things. The chemical industry currently utilizes natural gas as the raw material. A proportion of the hydrogen required for synthesis is already contained in the steel mill gases. Why not, wondered Achatz, produce the extra hydrogen required from surplus electricity generated from renewable energies? This would reduce the consumption of natural gas, a valuable energy source, cut CO_2 emissions, and stabilize the power grid. The research project aims to develop technologies which make this economically feasible.

From this unconventional idea following preparatory work with the Max Planck Institute for Chemical Energy Conversion (MPI CEC) the content of the PLANCK project was defined. In the "Platform for Sustainable Chemical Conversion" ThyssenKrupp started working with partners from industry and research from December 2013, who since then have been promoting the first cross-industry approach aimed at the use of CO_2 in chemicals production. The central idea: A cross-industry solution with utility providers and additional technology companies on board promises better results than the isolated efforts to reduce CO_2 emissions that have been pursued to date. If the technology transfer project, which is scheduled to last ten years, becomes a success, the key steel, chemical, and energy industries will interlink their value chains in future – jointly saving valuable raw materials and reducing CO_2 emissions.

The PLANCK idea: Steel mill gases contain, among other things, carbon monoxide, carbon dioxide, hydrogen, and nitrogen. When combined with additional hydrogen from wind power, they can produce natural gas, methanol, and ammonia.



Flexible catalysts for CO_2

"The prospects for success are good because the basic chemical processes and the required technologies are largely known," says project manager Markus Oles. Yet the goal is ambitious: Thanks to PLANCK it is hoped that one day almost all CO_2 emissions from steel production can be transformed chemically. Until then, however, the researchers and developers still have a few challenges to overcome. For example, the steel mill gases first need to be cleaned and prepared – a research task on which the MPI CEC and the Fraunhofer Institute for Environmental, Safety, and Energy Technology (UMSICHT) are working.

The greatest challenge, however, comes from carbon dioxide itself: Chemically CO_2 is extremely inert. The chemists therefore need catalysts if the gas is to react with other substances to form new compounds such as methanol or methane – and large quantities of energy. The catalysts facilitate the chemical reaction by reducing the required activation energy without being consumed themselves. The MPI CEC is developing special catalysts that can respond flexibly to the sharply fluctuating supply of green electricity.

Steel production consumes large amounts of energy – but can also provide raw materials for synthesizing base chemicals.

Without electrical energy PLANCK cannot reach its ambitious target. "If the plan is to completely convert the CO_2 contained in steel mill gases, this will not work without additional hydrogen," explains Ralph Kleinschmidt, technical head of department at ThyssenKrupp. This hydrogen is intended to come from water electrolysis using wind and solar power, which is why ThyssenKrupp and the Duisburg-based Center for Fuel Cell technology (ZBT) are working on new economical methods for producing the gas. Because the electricity comes from completely renewable sources, PLANCK's carbon footprint would remain exemplary.

Moreover, the researchers can kill two birds with one stone: Instead of converting green electricity that is no longer needed into hydrogen and producing electricity from it again later on, surplus production from renewable sources could ideally flow directly into the production of base chemicals. That is the aim – and one of the great benefits of the project. If this grid optimization succeeds with the help of the utility providers, PLANCK could through the stabilization of power grids make a substantial contribution to the success of the switch to sustainable energy.

The conversion of steel mill gases into fuels and fertilizers may still seem a distant dream right now – yet the developers intend to gather initial operating experience in a realistic steel mill environment as early as 2015. Tests will then be conducted for two to five years on how the newly developed techniques are proving effective in practice. Initial pilot and test facilities should be put into operation in seven years' time, and commercial implementation with an investment volume of over €1 billion is planned from 2022. If the project proves a success, PLANCK could usher in a sustainable structural change in Germany's key industries through an intelligent network of value chains. The project would then not only help reduce CO_2 emissions and save resources but also safeguard jobs and make Germany more sustainable as an industrial location.

TEXT: PETER HAHNE

The power couple

The switch to sustainable energy will not succeed without new storage devices for electricity generated from renewable sources. ThyssenKrupp is backing two technologies that complement each other brilliantly: redox flow batteries and electrolysis for the production of hydrogen.

TEXT: HANS SCHÜRMANN

The future energy system in Germany is supposed to guarantee a sustainable and safe supply generated from renewable sources. This may be good for the environment, but it confronts energy producers with a huge problem. This is that wind turbines and photovoltaic arrays do not produce power continuously: The energy that they generate is heavily weather-dependent. For this reason, energy suppliers and network operators will in the future need storage devices that can keep the network balanced. These will be able, for example, to absorb surplus electricity in high winds and supply this to the network in calm conditions.

Energy storage devices are already playing a major part in balancing electricity supply and demand. Globally, there is currently storage capacity of more than 100 gigawatts in pumped storage power stations and around one gigawatt in batteries and compressed-air storage devices. However, this will not be enough as renewable energy continues to expand: according to a study by the Boston Consulting Group, global demand is going to rise to 330 gigawatts by 2030.

From 2015, the Boston Consulting Group expects storage devices already to account for an annual market volume of €4-6 billion. From 2020, this figure is projected to stand at more than €10 billion each year. It is no wonder that more and more companies are investing in the development of new energy storage devices. ThyssenKrupp's Industrial Solutions business area plans to benefit from this growing market in two ways: by developing redox flow storage technology all the way to solutions in large-scale production and by developing a cost-optimized electrolysis process for the production of hydrogen.

These two technologies complement each other brilliantly. While the redox flow battery is able to absorb current peaks for several hours, electrolysis – as the basic component of all "power-to-gas" concepts – can be used to store renewable energy in large quantities and for a long period in the form of chemical energy, either as hydrogen or as synthetic natural gas which is stored in salt domes or added to conventional natural gas in pipelines.

The storage of large quantities of energy in electrochemical systems requires electricity storage devices that can be expanded at will. "Vanadium redox flow batteries, in particular, have highly promising potential for development in this respect," says Dr. Niels Bredemeyer, who is in charge of the development of this specific energy storage device at ThyssenKrupp Industrial Solutions. In his opinion, its greatest benefits are these: a high level of efficiency, a modular structure, and separate scalability of maximum capacity and quantity of energy stored. In addition, unlike pumped or compressed-air storage devices, they are not dependent on geographical factors and can be used almost anywhere.

High efficiency level of up to 80 percent

With redox flow batteries, the electricity is stored as chemical energy in two large tanks, where salts – in this case, vanadium salts – are dissolved in inorganic acids. The larger the tanks, the more energy they can hold. The two tanks are connected by pipes and pumps to one or several electrochemical cells ("cell stacks"). When power is drawn, the chemical energy is turned back into electrical energy. "The number of cells, or the total cell area, determines the maximum capacity of the storage device," Bredemeyer explains. "The efficiency level is up to 80 percent."

This new redox flow battery technology for large-scale production is still at the development stage. In 2012, ThyssenKrupp experts developed a first laboratory-scale cell, which is now being operated successfully at the technical center of the Energieforschungszentrum Niedersachsen (Energy Research Center of Lower ⇢

Wind turbines are not governed by demand. **This is why we need new power storage devices.**

Electrolysis cells at work.

Saxony, EFZN) in Goslar. The Group is currently working on the development of a modified cell with a larger active cell area. This will move next year to the new test facility at the ThyssenKrupp Industrial Solutions research and development center in Ennigerloh, where it can be trialed in continuous operation.

"Our aim is to achieve an active cell area of more than 2.5 square meters. So far, in practice, it is around 0.4 square meters," Bredemeyer says. "This will enable us to build an industrial storage device with an initial size of 20 megawatts and a capacity of 200 megawatt-hours. This will mean a significant reduction in the capacity-related costs of energy storage."

Industrial storage device with 200 megawatt-hours planned

The team is working with universities to increase the cell area as quickly as possible – but not all the components that would make this possible are available yet. "Our know-how lies in constructing the electrochemical cell, and especially in optimizing electrolyte flow," Bredemeyer says. The team achieved the first increase in capacity by a factor of ten within a year and a half. The experts are now tackling the next step: another increase by a factor of ten. It is planned to achieve the target cell area in 2016.

Hydrogen storage devices have even greater energy density than batteries. The idea behind this is that surplus electricity breaks water down into hydrogen and oxygen by electrolysis. The hydrogen is then stored in underground salt caverns: at a pressure of 200 bars, for example, the energy density is 200 kilowatt-hours per cubic meter. This is more than 50 times the figure for compressed-air storage devices.

As with redox flow batteries, ThyssenKrupp is thinking big here. "Our electrolyzer concept will enable us to achieve power input of about ten megawatts per unit," says Jens Wilhelm Kuhlmann, who is responsible for the development of the electrolysis system. "In order to win out against other systems, we need to reduce the cost of building the devices and optimize the efficiency of the electrolysis of water." This is why the developers have decided to devise a solution of their own. It is based on ThyssenKrupp's long-established chlorine alkali electrolysis system, the 100,000th unit of which was sold recently.

"There is a good chance that our alkali process will keep our investment costs 3.5 to 5 times lower than for rival processes," the expert says. "Simultaneously, we are seeking an efficiency level of up to 80 percent." ThyssenKrupp started development work in 2013. The first laboratory-scale device is already in existence – it is at the Gersthofen technical center near Augsburg. The next planned step in the development process is a pilot plant. The full electrode area of 2.7 square meters is due to be in operation by the end of the year.

We need »BATTERIES and HYDROGEN STORAGE DEVICES«

Dr. Thomas Turek is Head of the Institute of Chemical Process Engineering at Clausthal University of Technology. In this interview, the expert in electrochemical processes compares various storage technologies.

techforum: What is the importance of energy storage devices for the success of the switch to sustainable energy?
Thomas Turek: In the context of the planned reorientation of our energy provision to renewable energies, the development of storage technologies is indispensable, because these energies are not available continuously. In addition to daily and seasonal fluctuations in sunlight levels, there are substantial variations in wind power. In order to meet demand, therefore, it will be necessary to build up high levels of overcapacity in renewable energies in the coming decades. However, the networks will not be able to buffer their fluctuating production volumes alone, and this is why we need new electricity storage devices.

There are already a range of different storage systems. What are the prospects for batteries and hydrogen storage devices?
Turek: It is unanimously agreed that storage devices will need to be used in the future to cover the full range of time and volume, from seconds to months and from kilowatt-hours to terawatt-hours. This is why we need to consider different battery types – meaning electrochemical storage devices – and storage devices in the form of energy-rich chemical compounds. Many battery types are already technically feasible, whereas hydrogen storage devices are still at the research and demonstration stage. The technologies currently being developed by ThyssenKrupp are particularly well suited for storing very large volumes of renewable electricity: large-scale batteries for several minutes to several days, and energy-rich chemical compounds such as hydrogen for weeks or months.

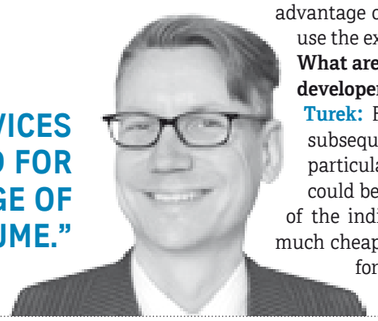
What will be the significance of redox flow technology?
Turek: Among the battery technologies being discussed at present, the redox flow battery has very high efficiency levels, highly dynamic performance, and an especially long life. I expect the increase in battery capacity that is being pursued now to lead to a marked improvement in the battery's cost-effectiveness.

Power-to-gas technology is brought up again and again, but critics say it has low efficiency levels. How well founded is that?
Turek: The efficiency level of the whole process chain is indeed limited, especially when the hydrogen is turned back into electricity in the reconversion process. However, from today's perspective, there is no alternative to the use of chemical storage devices. For the electrolysis of water, as the first step in the process, there are actually a variety of technologies which are currently being worked on intensively. By using chlorine alkali electrolysis, which is now very well developed, it may be possible to build highly efficient electrolyzers which will produce hydrogen on the basis of renewable energies in a capacity range up to several hundred megawatts. This hydrogen could then be used directly – for example, to operate fuel cells. At present, however, the conversion of hydrogen with carbon oxides into synthetic natural gas – known as methanization – is preferred. The big advantage of this additional step is that we could then use the existing natural gas infrastructure.

What are the biggest challenges that the developers need to overcome?
Turek: For both the electrolysis of water and the subsequent production of synthetic natural gas, the particular need is to improve cost-effectiveness. This could be achieved by improving the efficiency levels of the individual steps in the process and by using much cheaper materials – for catalysts and electrodes, for example.

INTERVIEW: HANS SCHÜRMANN

"STORAGE DEVICES NEED TO BE USED FOR THE FULL RANGE OF TIME AND VOLUME."



Everyone is a winner

Cross energy management offers a ray of hope: if consumers can adapt flexibly in future to the current supply of electricity, power grids will continue to operate stably and the costs of the switch to sustainable energy will remain manageable. ThyssenKrupp is working on solutions especially for industrial locations.

TEXT: ALEXANDRA GROSSMANN

You could almost set your watch by it – because electricity consumption in Germany follows a fixed daily routine: When, for example, the coffeemakers start up at seven in the morning, consumption across German households is far higher than at night. A further peak follows in the evening until demand starts to drop off again. Over the course of a day, this demand fluctuates between 40 and 80 gigawatts.

Conventional power stations currently provide this power according to fixed schedules – with generation following consumption. In the future, it will be exactly the other way round, because then we will be much more dependent on fluctuating sources such as sun and wind. "For that reason, our energy system has to change completely," says Friedrich Löser, Head of ThyssenKrupp's TechCenter Control Technology in Munich, which focuses on innovative system solutions in drive, control, and automation technology. "This means that in the future consumers will need to adapt to how much electricity the renewable sources will be able to provide at any given time," adds Löser.

There are two ways of maintaining the system's balance: Storing surplus electricity, for instance in batteries or in the form of hydrogen, or adapting demand to the current supply. Löser is investigating the second option. "Industry is easily the biggest consumer of energy in Germany," he explains. In addition, the routine of consumption in households could hardly be changed. "We will not be able to stop people getting up in the morning and making themselves a cup of coffee," sums up Löser in a nutshell.

ThyssenKrupp is therefore relying on the third group of electricity users. "We can certainly have an influence on industries that consume many megawatts of power," notes Löser, adding, "We can try to control and organize production processes so that consumption adapts to the supply of renewable energy." This would have a huge and immediate impact: The ThyssenKrupp steel mill in Duisburg alone turns over as much energy as the whole city of Berlin. "In Berlin we are dealing with three million individual consumers, whereas the steel mill in Duisburg is just a single customer – very different leverage effects are therefore possible in industry."

This is where cross energy management (CEM), also known as load management or demand-side integration, comes into play: The aim is for the major industrial electricity users to adjust their demand for power and thus their production processes more closely to the supply of renewable energies. To achieve this, they must structure their organization and their workflows more intelligently and more flexibly – in this way industry can make a key contribution to a stable power grid and to the success of the switch to sustainable energy.

The current electricity price is the signal for the start of production

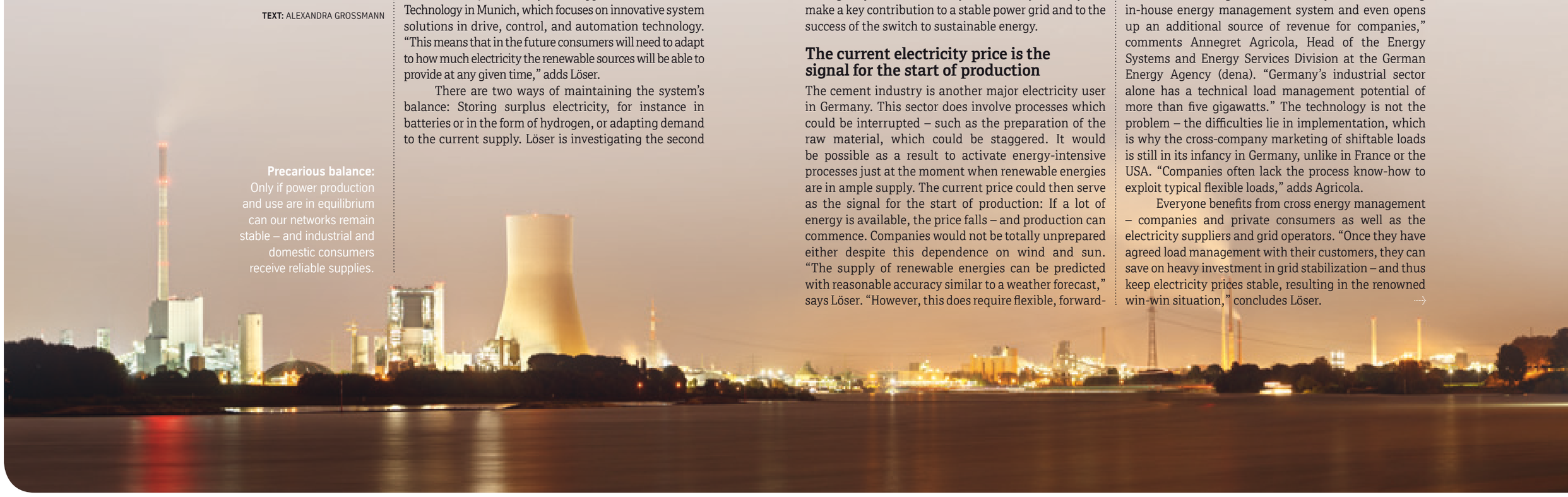
The cement industry is another major electricity user in Germany. This sector does involve processes which could be interrupted – such as the preparation of the raw material, which could be staggered. It would be possible as a result to activate energy-intensive processes just at the moment when renewable energies are in ample supply. The current price could then serve as the signal for the start of production: If a lot of energy is available, the price falls – and production can commence. Companies would not be totally unprepared either despite this dependence on wind and sun. "The supply of renewable energies can be predicted with reasonable accuracy similar to a weather forecast," says Löser. "However, this does require flexible, forward-looking production planning, ensuring that the energy is used when the price falls to a relatively low level."

None of this exists yet. "Such an intelligent system is only being considered at present. We are currently working on suitable processes and techniques," says Löser. "It is our aim to work out the technical as well as the operational principles of cross energy management." The benefits for companies and society would be great: According to a study conducted by the Fraunhofer Institute for Systems and Innovation Research, Germany could save some €5.6 billion per year through more efficient electricity management. Conversely, the changeover to more flexible electricity consumption would not be too expensive – bearing in mind that modern industrial plants are highly automated these days and major changes to hardware would not be necessary as a rule. However, the energy suppliers would have to reimburse companies adequately for load management: If companies are able to switch off loads on demand or use surplus energy, they can use this to build up a new business.

Dr. Friedrich Löser is Head of ThyssenKrupp's TechCenter Control Technology.

"Load management fits ideally into an existing in-house energy management system and even opens up an additional source of revenue for companies," comments Annegret Agricola, Head of the Energy Systems and Energy Services Division at the German Energy Agency (dena). "Germany's industrial sector alone has a technical load management potential of more than five gigawatts." The technology is not the problem – the difficulties lie in implementation, which is why the cross-company marketing of shiftable loads is still in its infancy in Germany, unlike in France or the USA. "Companies often lack the process know-how to exploit typical flexible loads," adds Agricola.

Everyone benefits from cross energy management – companies and private consumers as well as the electricity suppliers and grid operators. "Once they have agreed load management with their customers, they can save on heavy investment in grid stabilization – and thus keep electricity prices stable, resulting in the renowned win-win situation," concludes Löser. ⇢



Precarious balance: Only if power production and use are in equilibrium can our networks remain stable – and industrial and domestic consumers receive reliable supplies.

Load must follow »generation«

How great is the potential for load management in Germany? The Energy Technology Society (ETG) within the Association for Electrical, Electronic, and Information Technologies (VDE) is looking into this issue. In a study it has established that we need a paradigm change in order to advance this topic further. What needs to be done is explained by ETG CEO Wolfgang Glaunsinger in an interview with **techforum**.

INTERVIEW: ALEXANDRA GROSSMANN

What conclusion does the VDE/ETG study on demand-side integration reach?
Wolfgang Glaunsinger: The study shows that we need a paradigm change in load management – because the switch to renewable energies will bring about increasing fluctuations in the power supply system. The expansion of power grids, flexible power stations, energy storage devices, as well as load management are required to compensate for this. This means that in the future load must increasingly follow generation.

Where does the greatest potential in this area lie?
Glaunsinger: Simulations and analyses conducted in our study have shown considerable potential for load management without the need for compromises on comfort or production losses. Practical examples have been confined to industry to date. In households and across trade, commerce, and services, there is still very little happening, even though it would be possible to create the technical and economic conditions for load management. We recommend the relevant upgrading of plant and equipment as well as the expansion of information and telecommunications infrastructures, including equipping households with smart meters and the introduction of variable tariffs.

What is the situation in industry?
Glaunsinger: We examined various sectors that are heavy users of electricity, including the chemical, steel, paper, and cement industries. From the sample surveys we then derived a projection for Germany. The results of our study show that industrial facilities are already optimized as far as the processes and the purchase of electricity are concerned. Yet companies are currently striving for electricity procurement which is as uniform as possible. The use of existing product storage devices or the expansion of storage capacity would allow additional load shifting potential to be utilized in many industrial processes in the future. With chlorine electrolysis, for example, production can be increased if a large amount of electricity is available on the grid. Conversely, production can be cut if electricity is in short supply and expensive at that moment in time.

How great is the potential for load shifting?
Glaunsinger: We came up with a figure of some five gigawatts. That does not represent the potential savings – the point is rather to shift electricity consumption to a different time range. The companies save money, nevertheless, because they gain a cheaper electricity tariff thanks to the shift in time, allowing them to reduce their production costs.

How much is that by comparison?
Glaunsinger: Germany's annual electricity consumption comes to some 600 terawatt-hours, of which industry accounts for about half and households, trade, commerce, and services the remaining half. In industry we could reasonably shift some ten percent of total consumption through load management – provided that the processes are flexible enough and ample storage capacity is available. Industrial companies are unanimous in their view that this will work only if the economic and legal conditions are right. That is unfortunately not the case today for the most part.

Why have hardly any specific measures been taken to date?
Glaunsinger: Because at the moment it is not worthwhile for companies to interfere in industrial processes. It is up to the politicians to create better conditions. Otherwise companies will not be willing to invest in new storage devices or other plant and equipment. But without such investment we will not reach the required flexibility for load management.

"IT IS UP TO POLITICIANS TO CREATE BETTER CONDITIONS"

Load management rather than construction of new power stations: Most nuclear power stations in southern Germany are going offline, but, at the same time, companies in Bavaria and Baden-Württemberg will continue to need secure electricity supplies in the future. To cover peak loads, flexible new power stations could be built there – or else power supply and demand could be matched through intelligent consumption management. A survey of companies in southern Germany shows that many have already gained experience of load management, mainly in order to reduce peak loads. However, there remains a lot of unexploited potential.

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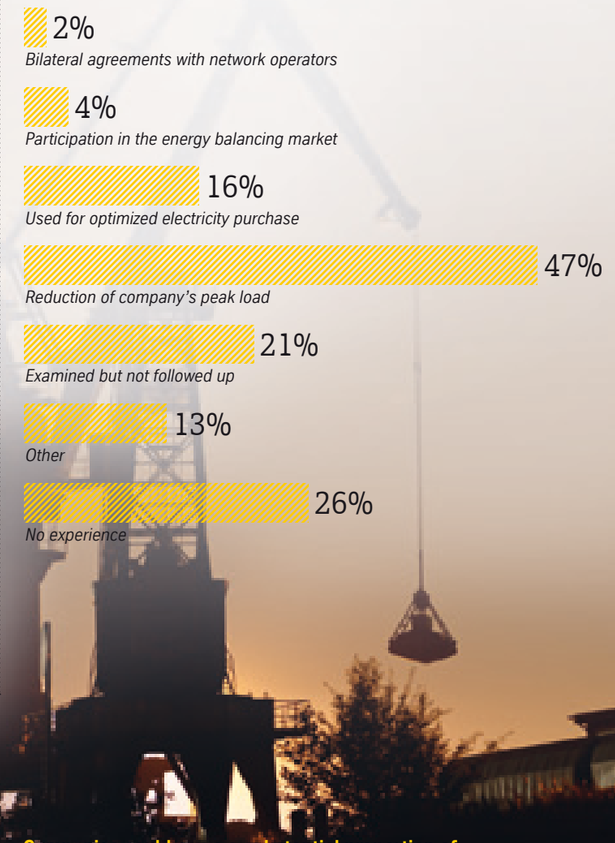
Load management currently carried out in companies: Please indicate what experience your individual facility/whole site has of the topic of load management (give more than one answer if appropriate).



Companies could move a substantial proportion of their demand through load management: For a period of two hours, more than 850 MW of electrical power could be switched off and deferred to a later time. For a shorter required period of only 30 minutes, this quantity would actually be more than 1.2 gigawatts. Energy-intensive sectors such as the chemical and steel industries, in particular, can make a major contribution to load management.

Source: Agora

Focus on efficiency

Energy efficiency is increasingly turning into a competitive factor and an engine of innovation. ThyssenKrupp plans to use its Groupwide Energy Efficiency Program (GEEP) to save energy systematically in the coming years. To do this, the company is counting on intelligent processes and engineering expertise. The program is being put into effect on a decentralized basis by the business areas and the Group's companies.

In the manufacture of rings and large-diameter bearings, **ThyssenKrupp Rothe Erde** is embracing a comprehensive energy management system under the DIN 50001 standard.

Many figures make sense only in context. Here is one of those: Each year, ThyssenKrupp requires around 80 terawatt-hours of energy for its facilities – for example, in the form of coal, gas, heating, and electricity. This is roughly equivalent to the annual electricity consumption of Finland. It is no wonder that the efficient use of energy is a strategic challenge for the Group.

However, this is not simply a matter of saving energy and cutting costs. "Greater energy efficiency is simultaneously an engine of innovation and a major contribution to environmental protection," says Thomas Fusshöller, Head of Sustainability, Environment, and CSR at ThyssenKrupp. In other words, especially for a technology company, the efficient use of energy is evidence of a strong innovative approach. It offers opportunities to develop new technologies and thus to get ahead of the competition. "For this reason, our efforts in the field of energy efficiency are a continuous challenge," Fusshöller says. "We are building here on our engineering expertise, which is the key to efficient processes and products."

This is certainly not a completely new topic, for ThyssenKrupp has long been a pioneer in energy efficiency. More than two-thirds of its energy consumption is already covered by an energy management system that meets the DIN 50001 standard: The Duisburg steel mill was the first of its kind in the world to receive certification under this standard. ThyssenKrupp is currently engaged in determining its objectives for a worldwide energy efficiency program. The idea behind this is not to impose one norm on the whole Group but to examine individual sectors systematically to identify energy-saving potential. Therefore, selected facilities are analyzed to see how energy can be saved through technical measures and improved processes.

One example is ThyssenKrupp Rothe Erde. This manufacturer of rings and large-diameter bearings, with sites in Lippstadt and Dortmund, is embracing a comprehensive energy management system under the DIN 50001 standard. "This is based on an exercise to make a detailed record of our energy consumption, for every process and every piece of machinery," says Heiko Tschich, head of department at the Dortmund plant. "Then we can use that to take individual measures."

There is savings potential, for example, in the intelligent shutting-down of individual pieces of machinery: In the past, rolling mills and machine tools were rarely switched off, partly because the process of switching off and restarting is complicated and susceptible to error. "It is not simply a matter of throwing a switch," as Tschich puts it. Therefore, the operators now have detailed descriptions to enable them to shut down their machinery in a controlled manner during scheduled breaks and stoppages and then restart it afterward.

One important component is the recording of energy data. "Only with up-to-date, transparent energy data is it possible to make the best assessment and to select projects," says Klaus Henke, Head of Technical Coordination. He adds that investment is still needed – for example, in people to record and evaluate the data. He also notes that even energy efficiency projects have to undergo a business assessment. "For instance, we included the increase in efficiency and the amount of energy saved as factors in a necessary replacement investment. In that case, we are expecting an efficiency increase of 30 percent and an energy saving of 2,500 megawatt-hours each year in gas," Henke says.

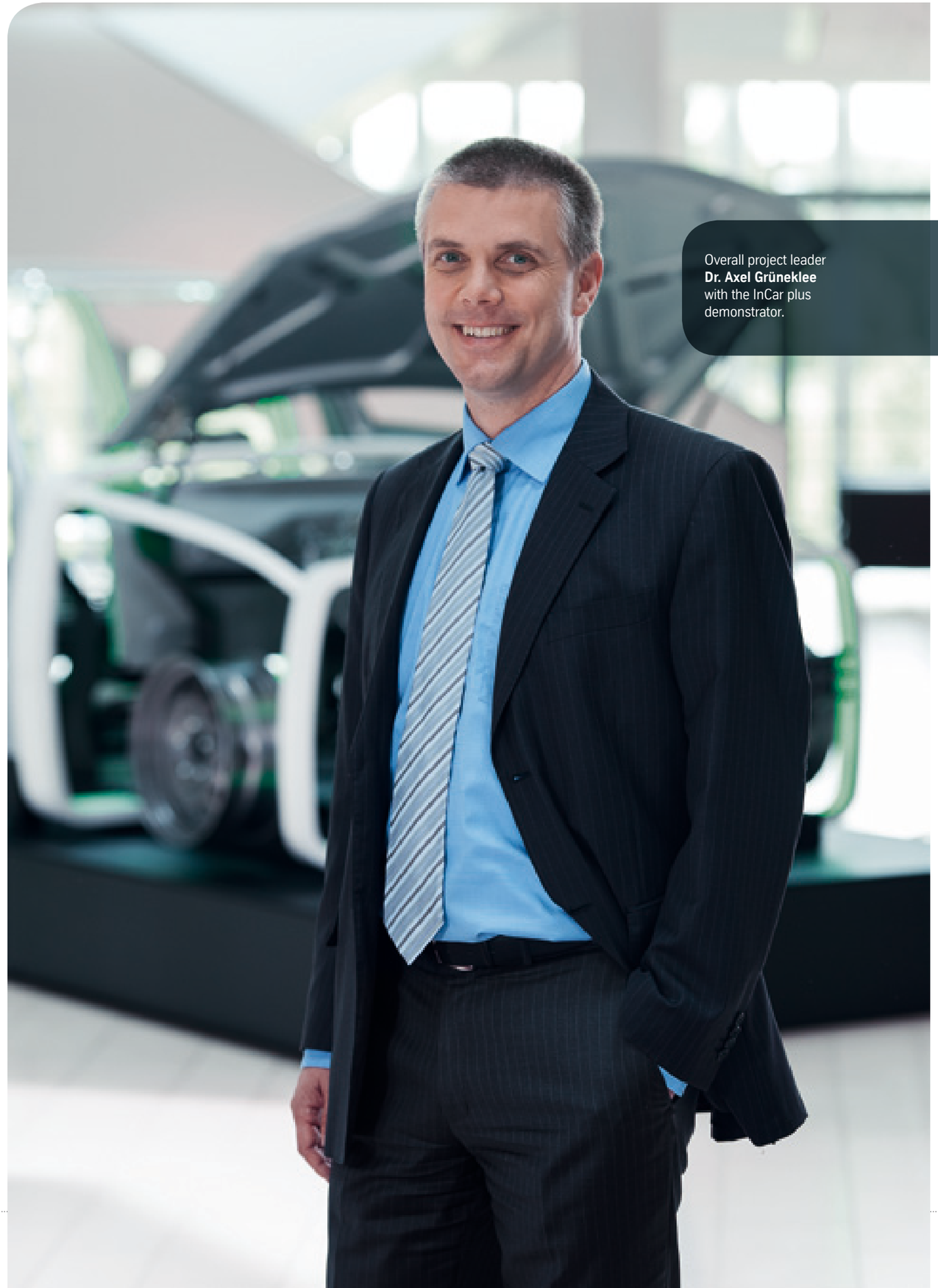
Efficient use of gas furnaces cuts costs by 30 percent

"We launched our efforts to boost efficiency as many as fifteen years ago," Tschich reports. At that time, it was simply about saving money – for example, after energy costs at the Dortmund plant rose sharply as a result of the switch to town gas. "Thanks to the more efficient use of our gas furnaces, our costs are now around 30 percent lower," Tschich says. "However, the new energy management system enables us to be even more efficient. It provides a structure and a system."

In the end, however, nothing will happen without the employees. Of course, Rothe Erde, like every company in the Group, has energy managers and energy officers to drive the program internally – but everybody has to play a part: "Every employee can and must make a contribution. We need to create a culture in which everybody thinks about improvements and the measures decided upon are supported," says Rainer Stanlein, energy manager at Rothe Erde, summing up the position.

The experience of Rothe Erde and other sites shows the way for more than 100 companies in the Group, each with annual consumption of more than ten gigawatt-hours, which have already been taking part in the Groupwide Energy Efficiency Program. A catalog of standard solutions is available to help small companies in the Group identify measures for improvement at their own sites. "Implementation of the measures will be monitored regularly using specific savings targets for the various business areas, entirely in the spirit of continuous improvement," says Marc Verheyen, Manager Energy Efficiency & Energy Management Systems.

TEXT: JOST BURGER



Overall project leader **Dr. Axel Grüneklee** with the InCar plus demonstrator.

The plan for the car of the future is to make it lighter, more economical, more environment-friendly, and more comfortable. This will happen if experts from all disciplines come together – as they are doing with InCar plus, ThyssenKrupp's biggest research and development project for the automotive industry.

TEXT: CHRISTIAN BUCK

Joining forces

Most drivers would probably be rather surprised if they were to put one of their smart aluminum wheel rims on the scales and then, for comparison, a modern steel rim. This is because, although aluminum is a light metal, the wheel made with high-strength steels weighs less. Nevertheless, the range of different aluminum designs seems to be simply infinite, compared with steel wheels. That could change soon, however, thanks to one of the projects in the InCar plus research program: "Our concept allows for a combination of attractive styling and minimum weight," says Markus Zörnack, an expert in lightweight construction at ThyssenKrupp Steel Europe in Dortmund.

More comfort and safety in lighter cars

If these new, light steel wheels establish themselves in the market, they will not merely help the driver to save fuel. Their whole environmental performance is better: The production of modern high-performance steels made from iron ore consumes much less energy than the manufacture of light metals such as aluminum. Of course, wheels are only one of many examples showing that the potential for optimization in automobile construction is still far from exhausted. More than ever before, innovation here requires communication and cooperation. On the one hand, product developers need close contact with experts working on new materials. On the other, they also want direct links with specialists in mass production.

ThyssenKrupp's automotive experts signed up to this interdisciplinary way of working in 2011, when they launched the Groupwide project InCar plus, which concludes in September 2014. It brought together a total of 15 sites in eight companies in the business areas Steel Europe, Components Technology, and Industrial Solutions. The objective was to find every component, from the radiator grille to the trunk lid, where ThyssenKrupp's engineers could optimize the weight, cost, sustainability, and performance. Everything was examined: Powertrain, chassis and steering, and body. This resulted in 30 projects, which in turn generated more than 40 innovations.

Although lightweight construction is a recurrent theme in new and further developments, Grüneklee and his colleagues were not bent on saving weight at all costs. "Ultimately, there is no environmental benefit if the ecological burden during production is so high that it cannot be canceled out even over the whole life cycle of the vehicle," the overall head of the project observes. He notes that it is also necessary to factor in the increased energy consumption in the construction of a low-emission car. "There are some lightweight solutions that, even with 200,000 km on the clock, will not reach the break-even point," Grüneklee explains.

For this reason, the InCar plus engineers applied stricter criteria than the law requires. Every proposed component had to pass a life-cycle assessment, meaning both an environmental and an economic cost-benefit analysis. Only those solutions that had a positive overall performance, ranging from materials production through to recycling, had any chance of success. What mattered ultimately was the leverage effect of every single euro invested. Carbon fiber reinforced plastic may be technically wonderful, but its manufacture is so expensive that it can be turned into economically viable solutions only in conjunction with newly developed, low-waste production processes, such as those for lightweight steering columns.

Further significant efficiency improvements are possible in the powertrain, chassis, and steering. "Switching from hydraulic to electric power steering alone reduces consumption by up to half a liter per ⇢

"LIGHTWEIGHT CONSTRUCTION IS NOT AN END IN ITSELF. THERE ARE SOLUTIONS THAT MAKE A GREATER CONTRIBUTION TO REDUCING EMISSIONS AT LOWER COST"

DR. AXEL GRÜNEKLEE

100 km," Grüneklee says. The further development and increased efficiency of these EPS (electric power steering) systems was one topic covered by InCar plus. "Our new column EPS power unit is making this technology available even for mid-range vehicles," Rainer Pudeg of ThyssenKrupp Presta Steering, head of the "chassis and steering" subproject, is delighted to note. The compact module is built directly into the steering column in the vehicle interior and is thus easier to protect against heat and damp. "The improved steering feel means that this solution is a true technical and economic alternative to conventional systems," Pudeg says.

The innovations are production-ready.

Special feature: Production suitability included

The innovations that Pudeg's project team has devised as part of InCar plus include a new, integrated damping adjustment valve. "Electrically adjustable dampers have very high switching dynamics, which means they respond extremely quickly in unforeseen evasive maneuvers," Pudeg explains. "As a result, we are increasing not only the level of comfort but also driving safety." He believes this product is already so far advanced that, if required, ThyssenKrupp could move very quickly to application development for customers.

This suitability for production was one of the aims of InCar plus: Many projects were trimmed so as to offer auto manufacturers assured solutions – in other words, to present the innovations in such a way that they could be incorporated into existing production processes as smoothly as possible. If new processes are required, their introduction is part of the package that ThyssenKrupp offers its customers. In addition, however, the InCar plus project also includes topics that are pioneering and display great potential for performance improvement and weight and cost reduction.

This applies, for example, to a lightweight engine hood made from Litecor, a new composite consisting of two thin steel panels and a middle layer containing a plastic mixture of polyamide and polyethylene. The processing of Litecor entails new requirements in relation to metal forming and joining technology, and the Steel Europe business area is working on solutions for auto manufacturers here in close cooperation with the Industrial Solutions business area. One other example of innovative product improvements through intensive cooperation with production specialists is the hybrid cylinder head cover. This module, with integrated camshafts and components made of plastic, steel, and die-cast aluminum, is not only an example of successful lightweight construction, but also reduces assembly costs and simplifies parts handling for customers. Thanks to the innovative design of the camshaft bearings, this complex assembly also has less friction loss and needs a lower oil flow to lubricate the bearings. "This reduces the demands on the oil pump," explains Claudius Rath, head of the "powertrain" subproject. "That is one of many small contributions toward meeting the emissions requirement of 95 grams of CO_2 per kilometer by 2021."

Most of these solutions improve the internal-combustion engine, because project leader Grüneklee and powertrain expert Rath agree with the Group's senior management that all-electric cars are not going to conquer the mass market in the immediate future. They see better prospects for hybrid powertrain systems, where an electric motor supplements the internal-combustion engine. "The electric powertrain is already an interesting area of activity for ThyssenKrupp," Rath says. "And its importance will grow further in the future." One innovation is coming from Thyssen-Krupp Steel Europe, a component for the core parts of an electric motor: the rotor and the stator. These are punched from thin, high-strength electrical steel. "We have optimized the mechanical properties and configured them for the centrifugal forces that occur in high-speed motors," Rath says. "This results in a perceptible increase in efficiency."

The powertrain expert is also proud of a transfer of know-how from the internal-combustion engine to electromobility. His team has replaced the normally solid rotor shaft with an assembled structure with a hollow interior, which can be used, for example, for integrating an active cooling system – this improves the electric motor's efficiency. "The rotor shaft is one of the components in an electric motor where we have been able to make significant weight savings," Rath says. He adds that the saving currently stands at 16 percent and that there is scope for even more. The joining process involved in making this part is something that the engineers know inside-out. It has been used millions of times over in production – and continually improved – for many years.

CHASSIS & STEERING

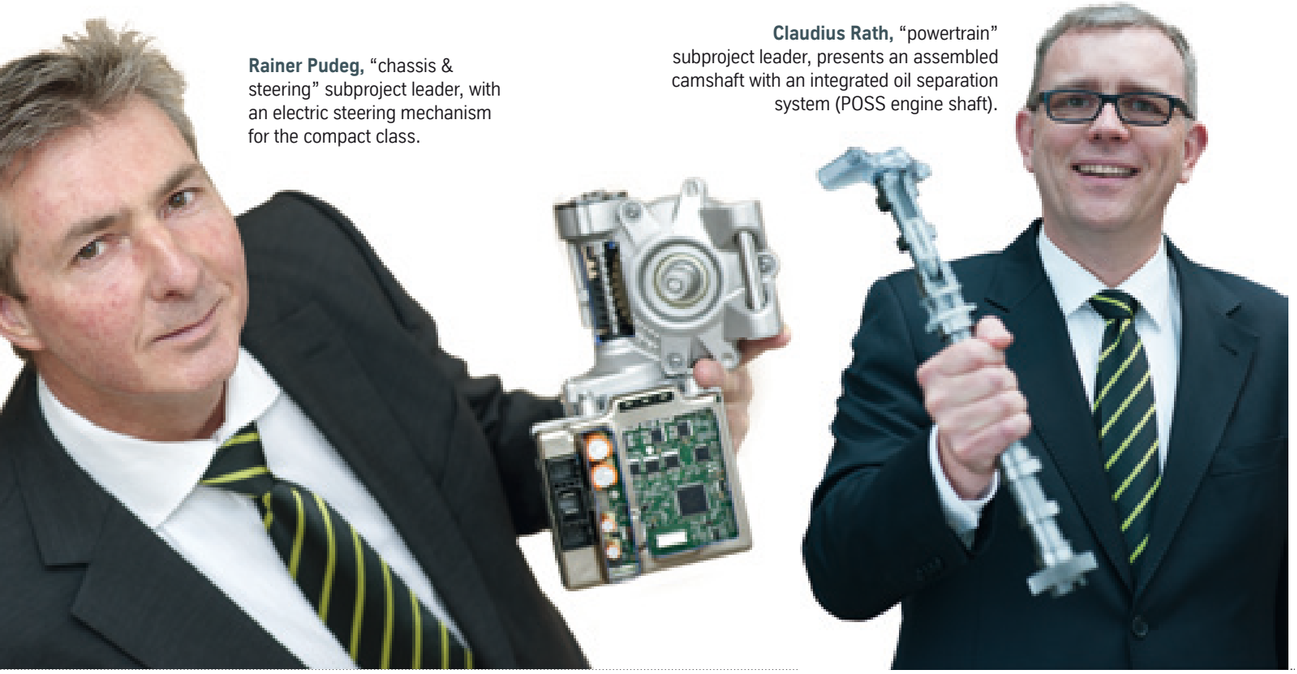
- **Vehicle suspension springs made from ThermoTecWire:** 20 percent lighter and much shorter.
- **Shock absorber tubes:** CFRP version saves up to 45 percent versus aluminum.
- **Integrated damping adjustment system:** Provides greater comfort, safety, and agility.
- **CFRP steering column components:** Reduce weight at component level by up to 60 percent.
- **Assembled steering racks:** 25 percent lighter than steering racks made from solid material.
- **Freely programmable steering angle actuators:** Allow many assistance functions.
- **Column EPS system:** Saves costs versus rack EPS systems.
- **Steer-by-wire experimental vehicle:** Helps the development of pioneering steering systems.
- **Hybrid steering shaft:** 35 percent lighter, with attractive lightweight costs.

POWERTRAIN

- **Exhaust systems made from density-reduced steels:** Do not heat up as much and offer greater corrosion resistance.
- **POSS separation system for oil in blow-by gases:** Creates space in the engine compartment and is more effective than conventional oil separation systems.
- **Function-optimized camshafts:** Improved manufacturing and coating processes reduce friction losses on camshafts.
- **Hybrid adjustable cam element:** Lightweight construction in variable valve lift systems allows fuel savings of up to five percent.
- **Hybrid cylinder head cover modules with integrated camshafts:** 15 percent less weight, 15 watt lower friction loss, and 30-40 percent lower oil flow.
- **Fuel cell stack made from stainless steel:** Allows a cost reduction with comparable performance.
- **Electric powertrain unit for hybrid vehicles:** Integrated into a lightweight steel rear axle subframe.
- **eTDC – new components for e-powertrains:** Integrated rotor and gear shafts reduce the weight and increase the efficiency level of e-motors.
- **Hollow cylindrical lightweight rotor:** Saves up to 16 percent in weight and creates space for active rotor cooling in the e-car.
- **New types of electrical steel:** Increase the torque of electric motors.
- **"Bondal E" composite material:** Halves noise emissions from stator of an e-motor.

BODY

- **Lightweight cockpit beam:** More than three kilograms lighter than steel solutions.
- **Bumper system with steel crash beam:** Saves up to 19 percent in weight at equal cost.
- **Multichamber steel profile:** Makes the longitudinal member 23 to 31 percent lighter.
- **A-pillar:** Ten percent less weight with reduced blocking of viewing angle.
- **B-pillar:** Cost and weight reduction through the use of new materials.
- **Litecor steel-polymer composite:** 14 components are made a total of 19 kilograms lighter, with equal performance.
- **Side doors made of Litecor:** Up to one-third lighter and suitable for mass production.
- **Multimaterial engine hood:** Weight benefit of up to 40 percent.
- **Seat components:** Up to 15 percent lighter as a result of new steel grades; as much as 37 percent with Litecor.
- **Lightweight steel wheels:** Lighter and more environment-friendly than aluminum wheels.



Rainer Pudeg, "chassis & steering" subproject leader, with an electric steering mechanism for the compact class.

Claudius Rath, "powertrain" subproject leader, presents an assembled camshaft with an integrated oil separation system (POSS engine shaft).

Markus Zörnack, "body" subproject leader, examines a multichamber longitudinal member made from super-high-strength steel grades.

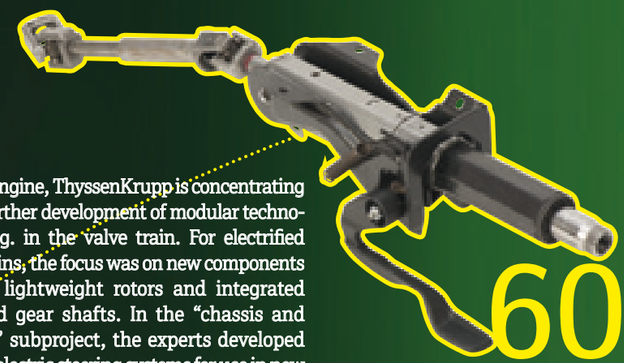
Innovations for the car of tomorrow

TEXT: CHRISTIAN BUCK

InCar plus is one of ThyssenKrupp's largest research and development projects. Its innovations will lead to a marked CO^2 reduction in a car's utilization phase. Here are six of them.

ThyssenKrupp has developed new products for the powertrain, chassis and steering, and body sectors in more than 30 projects with over 40 individual solutions. The focus was on environment-friendly solutions in all aspects of energy efficiency, electromobility, and lightweight construction. Whether it is weight, economy, sustainability, or functionality, each innovation will surpass the present state of the art for at least one of these criteria. For weight, the solutions open up potential savings of up to 60 percent, and for cost the figure is up to 20 percent. What is more, the whole life cycle came in for examination: the ecological performance of the InCar plus solutions demonstrates that they can have an environmental impact in all the phases of a product's life.

In the "powertrain" subproject, the experts addressed the internal combustion engine and electrified powertrains. For the internal-combustion engine, ThyssenKrupp is concentrating on the further development of modular technologies, e.g. in the valve train. For electrified powertrains, the focus was on new components such as lightweight rotors and integrated rotor and gear shafts. In the "chassis and steering" subproject, the experts developed low-cost electric steering systems for use in new vehicle classes, as well as multimaterial shock absorbers and steering shafts. In addition to making a contribution to weight reduction, the aim was to achieve an improvement in comfort and safety and to find solutions that would be suitable for production. The "body" subproject likewise concentrated on economical lightweight construction. Here, hot forming played a key part, as one of the most important technologies for safety components.



60 %
weight reduction at component level

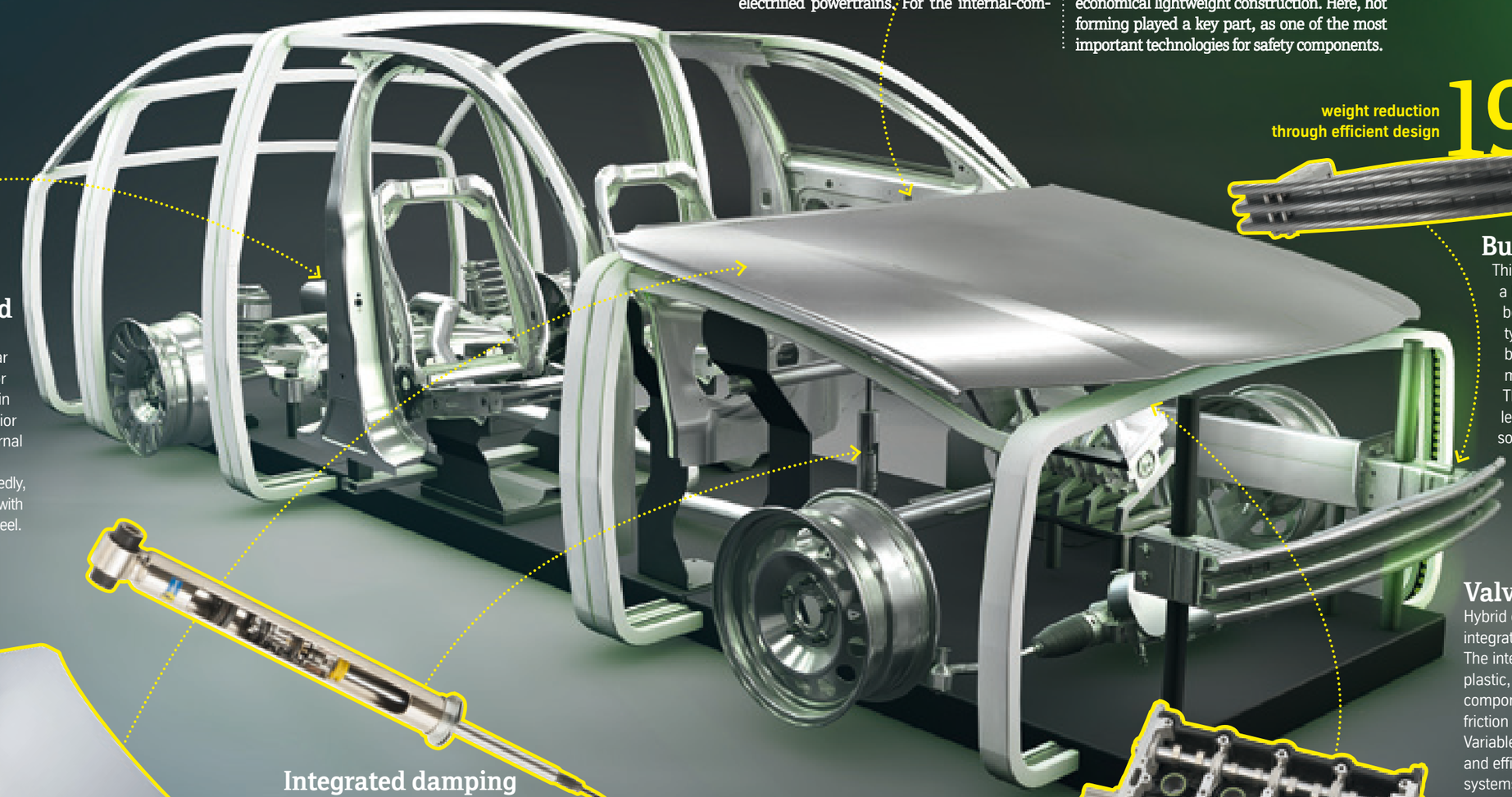
CRP steering column

Carbon fiber reinforced series. One project was aimed at validating production processes for CRP structures.

16 %
weight reduction and integration of functions in the rotor

Electric/hybrid powertrain

The assembled, modular rotor of an electric motor saves up to 16 percent in weight. The hollow interior allows for an active internal cooling system, which improves efficiency markedly, especially in conjunction with high-strength electrical steel.



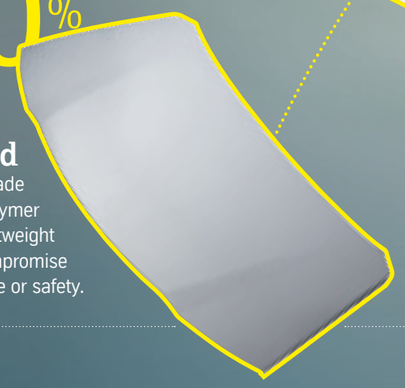
weight reduction through efficient design 19 %

Bumper system

This bumper system with a hot-formed steel crash beam is as light as a typical aluminum structure but much cheaper to manufacture. The cost is at the same level as the reference solution made from steel.

Integrated damping adjustment valve

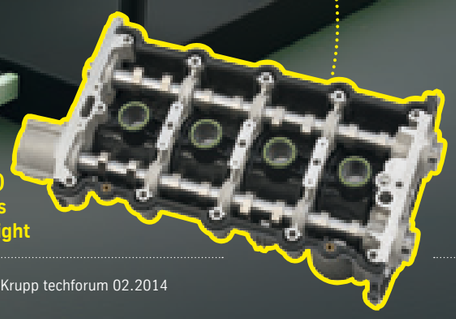
The pilot-operated pressure relief valve combines driving comfort and safety with agility. It switches quickly and offers a high spread of steam power with high adjustment dynamics even at the pressure stage.



20 %
weight reduction through the use of Litecor

Engine hood

The bend-proof composite made of two steel panels with a polymer core means successful lightweight construction with no compromise on performance or safety.



15 % less weight

Valve train

Hybrid construction with integrated camshaft modules. The intelligent combination of plastic, aluminum, and steel components reduces weight, friction loss, and oil flow. Variable valve train systems and efficient separation systems for oil in blow-by gases can still be integrated.

Think tank

for Industry 4.0

The origins of progress at car factories often lie in Berlin: **inpro** is the place where ThyssenKrupp, VW, Daimler, Siemens, and SABIC have come together to conduct research for the car production of the future.

TEXT: ULF FROITZHEIM

Gerd Esser is an engineer – and not some marketing promoter who might hit on the idea of declaring a "fourth industrial revolution". Nevertheless, he considers it "right and proper" that the expression "Industry 4.0" has gained prominence in the media. This is because Esser is the head of one of those pioneering companies without whose decades of preliminary work the advocates of the 4.0 concept would have nothing to offer: the "Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH" (**inpro**). ThyssenKrupp is one of its partners, alongside Volkswagen, Daimler, Siemens, and SABIC.

"Industry 4.0 is the sum of all the ideas that were already around at the time when people were talking about computer-integrated manufacturing," is the **inpro** chief's definition. He makes a short dramatic pause before going on: "plus a thousand-fold increase in the performance of computers and digital networks, plus new IT architecture and human-machine interaction concepts à la Google Glass." Does that not mean that this revolution is really more an evolution? Of course, the version number could equally well be 4.1 or 3.11, Esser concedes. Ultimately, however, he thinks the question is redundant.

> "We try to organize things so as to create win-win combinations for the partners involved."
> **Dr. Gerd Esser, inpro Managing Director**

There is good reason for his detachment: **inpro** experts were already involved when the revolution number jumped forward to "3" – this enables him to stand back somewhat from the current hype. At that time, industry was just learning how to program robots, and affordable computers fired the imagination. At the end of 1982, leading figures from the political, scientific, and business worlds met for a conference in Berlin. The new Chancellor, Helmut Kohl, wanted to bolster the isolated city's status as a business center, and his Research Minister, Heinz Riesenhuber, pressed companies not to miss the opportunities offered by IT and microelectronics. This gave Günter Spur his chance: the legendary "Pope of production" and Fraunhofer Institute professor was present at the birth of an organization that was designed to put his vision of the "factory of the future" into practice.

Pooled resources

Spur's plan was to bring all the industrial sectors involved in car production – vehicle manufacturers, factory equipment providers, suppliers – together in this "Society for Machine Intelligence," as the think tank was originally going to be named. Even while the conference was in progress, the heads of Daimler-Benz, VW, BMW, and Siemens committed themselves to taking part. The Federal State of Berlin also signed up. With the exception of BMW, the founding partners are still there, joined by ThyssenKrupp and the plastics specialists of the former General Electric division GE Plastics, which is now part of the Saudi Arabian chemicals giant SABIC.

The five industrial partners are simultaneously **inpro's** core customers. The joint venture's main activities are communal projects that benefit all the parties. The fact that Daimler and VW are fierce rivals in the market does not prevent them from collaborating pragmatically – for instance, on production software. For example, **inpro** specialists played a key part in defining the new, open data exchange format AutomationML (Markup Language). Such standards are important, because all manufacturers are suffering equally from the present tangle of different systems. The Berlin experts' strengths also include simulation software, which enables future production processes to be played out in detail and optimized.

"**inpro** is an external pool of know-how for our experts," enthuses the innovation manager Alexander Gulden, who represents ThyssenKrupp Components Technology on the **inpro** project board. He describes the think tank, which is networked with a wide range of technical universities, as both a "bridgehead into the research landscape" and a networking platform. It is a place where experience is exchanged and cooperation takes place at all levels – from engineers in specialized technical departments needing to solve a specific detailed problem, through to board members responsible for production getting to grips with long-term trends such as lightweight construction or the digital factory. **inpro** has the attraction here of being neutral territory for all the participants, where they can come together on an equal footing to seek the most efficient solution. "This does not work so well in a traditional client-contractor relationship," Gulden says.

For the **inpro** chief, Esser, one of the most exciting topics in the immediate future is composite construction: "If we combine completely different lightweight construction materials, it cannot be a solution to continue working with a wide range of joining technologies." He believes that the key technology for reducing this complexity is bonding. This, too, will again create work for his software specialists: they will need first to simulate the factory in which the car of tomorrow is bonded together.

The partners in the **inpro** joint venture, founded in 1983, are Daimler, SABIC (Saudi Basic Industries Corporation), Siemens, ThyssenKrupp, Volkswagen, and the Federal State of Berlin. About 60 technical/scientific employees and around 30 student trainees work on projects in the fields of process simulation, production systems and information processes, joining and materials technology, and production testing technology. **inpro** has a turnover of €9 million.

Matthias Wissmann, a lawyer, has been President of the German Association of the Automotive Industry (VDA) and Vice President of the Federation of German Industries (BDI) since 2007. He was Federal Minister of Transport from 1993 to 1998.

We are a world »leader«

Manufacturers and suppliers are driving the car's development with high investment in research and development. Matthias Wissmann, President of the German Association of the Automotive Industry, says the sector is ideally positioned for the future.

techforum: The automotive industry is facing major upheavals. What is the greatest challenge at present?
Matthias Wissmann: Transportation and the automotive industry are experiencing a phase of upheaval. This is because urbanization is advancing more and more quickly, fuel is becoming more expensive, and resources are growing scarcer. At the same time, the rate of motorization is rising, especially in emerging markets, and freight transportation is also growing strongly. This means we need to develop vehicles that are efficient and sustainable. There is also the trend toward digital networking, which is now also finding its way into the automobile. For all these issues, we need to develop solutions that are fit for everyday use, in both the private and the commercial realm. This is where I see the greatest challenges.

What technical innovations will be decisive in surmounting these challenges?
Wissmann: We are going to need a lot of different solutions – in efficiency, for example. The road away from oil will not be built with just one technology. Rather, the task is to save fossil fuels, to supplement them with biofuels and, in the long term, to replace them with alternative fuels and powertrains. Electromobility, in all its forms, will be a key technology here.

In what position do German manufacturers and suppliers find themselves in these areas of innovation, compared with other countries?
Wissmann: An extremely good one! The most innovative companies in the world include a large number of German auto manufacturers and suppliers. With global research investment of around €27.5 billion each year, they are doing a huge amount to drive the optimization of traditional powertrains and the development of new technologies – and international assessments show that they are reaping the benefits. Among supplier nations for electric cars, for example, the German automotive industry is currently in pole position. No other country has a bigger range of electric models! To put it another way, Germany's auto manufacturers are the world leader in the development and production of highly efficient, safe cars that hold their value. This is also acknowledged by customers: Nearly one in five cars sold worldwide bears a German name, and in the premium sector we actually have a market share of just under 80 percent.

How has the automobile producers' development process changed in the past ten years?
Wissmann: A model life cycle still lasts between five and seven years, and halfway through that period there is usually a model update or facelift: Models are then often also given additional standard equipment. This has not changed much. However, the number of variations on offer from German manufacturers has increased significantly in recent years – facilitated by new production technologies, which are making plants more and more flexible. One challenge for engineers is the growing range of materials: in order to reduce weight, particular use is being made of aluminum and carbon, alongside high-strength steel. We are also seeing a significant change in software installed in cars, where there is a marked acceleration. Intervals between updates are sometimes as short as six months. This represents a particular challenge for manufacturers and suppliers: They need to harmonize the short development cycles of consumer electronics with the longer development cycles of the automotive industry. ⇢

"THE ROAD TO E-MOBILITY IS NOT A SPRINT BUT A LONG-DISTANCE RACE"

MATTHIAS WISSMANN

Automobile development is being driven not just by manufacturers, but also by suppliers. What part are they playing today in innovations?

Wissmann: Our suppliers do not merely account for 75 percent of a German car's value chain: They also make a considerable contribution to the innovative strength of the German automotive industry. Many of them are "hidden champions", because they are global market leaders in their technological fields, often without being noticed by the public. With their technological innovations, large and medium-sized suppliers underscore Germany's outstanding reputation as a center of automobile development and production. Many of them have a global presence and took the necessary investment decisions at an early stage to keep their operations competitive in the long term. It is this mix of big manufacturers and large and medium-sized suppliers that makes our automotive industry so strong.

How are suppliers responding to their growing importance for vehicle development?

Wissmann: Suppliers have adjusted to the new situation and are seeking cooperation with manufacturers at the earliest opportunity – this brings great benefits for both parties. Some suppliers have set up their own subsidiaries for this purpose, to deal exclusively with development orders. In addition, for many years there have been independent development service providers, which are constantly expanding their capacity. However, this trend cannot be taken for granted, because suppliers' innovative capability depends on many factors. The main considerations are the know-how of skilled workers and the appropriate general conditions. For this reason, we need sound regional economic policy, which encourages companies' capacity to innovate and invest and does not weaken industry and medium-sized businesses. This includes limiting rises in unit labor costs and maintaining proven instruments for ensuring flexibility in the labor market.

What expectations do auto manufacturers have of innovations developed by suppliers?

Wissmann: The challenge for both parties is to work together to develop production-ready innovations that offer customers added value. What is decisive, therefore, is not only the technology but also the practicability and cost of innovations. Only then can we expect customers to be willing to buy. These innovations improve the manufacturer's competitive position, but they have to be worthwhile for suppliers as well, or else they will not be able to do the necessary long-term preliminary work.

What part do you think the internal combustion engine will play in the next ten years?

Wissmann: For the foreseeable future, diesel and gasoline engines will continue to account for the bulk of individual mobility. We expect vehicles with alternative powertrains to have a share of sales of about five percent by the end of this decade. This means we are dealing not with a sprint but with a long-distance race requiring great endurance. Nevertheless, it is the correct course to take, because, one day, the savings potential of the internal-combustion engine will be exhausted. This is why it is necessary to develop alternative powertrains.

How do you think the long-term future of mobility will look?

Wissmann: Still better fuel efficiency – and even "local zero emissions" in the case of electric cars – as well as even faster and easier-to-use in-car online communications, plus even greater safety: These are the key elements of "mobility for the future". Despite all the change, however, there is also one constant: People's desire for individual mobility and a car of their own. This desire for movement transcends cultures and continents. It is as present in Asia and America as it is in Europe. The German automotive industry is working constantly to meet these customer desires with top quality.

INTERVIEW: CHRISTIAN BUCK

Germany's top motor industry lobbyist believes suppliers make a considerable contribution to the sector's innovative strength.

The internet of ELEVATORS

Real-time data in the cloud increase availability.

ThyssenKrupp Elevator together with Microsoft and the IT specialist CGI has unveiled a networked monitoring system for its elevators which is breaking new ground worldwide: Sensors in the equipment supply data about the state of systems, sending them via the internet to the cloud – including information about the drive motor temperature, cab speed, and door functioning. As a result, elevators are for the first time becoming part of the "Internet of Things" in which intelligent objects are interconnected through cloud technology. The data are processed intelligently and made available to the service engineers. Instead of responding to faults, they can now use real-time information and take action even before an elevator breaks down – this increases elevator availability considerably. And because the new system can also receive data, the service engineers can in future put the elevator into diagnostics mode remotely or send it to another floor. The new system reduces traveling time, improves efficiency, and lowers costs.

Remote control for shock absorbers

Drivers have not had too much choice to date. At the push of a button three different driver-selectable settings were available: "normal", "comfort", and "sport". Otherwise the systems were passive: whatever had been set could not be changed – at least not until the shock absorbers were replaced. That is now changing with the iRC app developed by Bilstein: via their smartphone customers can now not only select predefined characteristics but also adjust all settings manually. "You notice the change in road handling immediately, without having to delve into the underlying technology," says Klaus Lepenies, Head of Car Integration at Bilstein. "The change from the passive to the active system – that is a real breakthrough."

New standard in hot forming

Hot forming is gaining increasing ground as a cost-efficient lightweight construction solution in body manufacture. ThyssenKrupp System Engineering together with Audi AG and Ebner Ofenbau has developed a line for manufacturing hot-formed parts that is setting new standards. It features technologies which include tailored tempering, enabling different strength levels to be created in a single component. The line is also prepared for hot trimming (simultaneous forming and cutting) and offers fully automated tooling changes, allowing production to be switched in extremely short changeover times.

Steel is still far from the end of its development process. ThyssenKrupp Steel Europe's trend researchers expect radical innovations in the future - including generative manufacturing processes as in the case of 3D printers.

INTERVIEW: CHRISTIAN BUCK
PHOTOS BY: NATALIE BOTHUR

Materials with a great future

Looking 5 to 15 years ahead: The trend researchers Dr. Marcus Rauhut, Dr. Lothar Patberg, and Christina Mendelin (from left) talked to **techforum's** Christian Buck about new hybrid materials and steels with a memory effect.

The setting could not be more appropriate: Beside the chairs is a model car body containing many innovations for vehicle construction. On the other side, technicians in overalls are working on steel panels, which will provide further prototype parts for energy-saving cars. Sitting in-between are Dr. Lothar Patberg, Head of Innovation at ThyssenKrupp Steel Europe, and the two trend scouts, Dr. Marcus Rauhut and Christina Mendelin. In the bustling applications hall for research and development at the Duisburg site, they look into the future for **techforum** and explain how serious trend research works.

techforum: Dr. Patberg, where have you left your crystal ball?

Lothar Patberg: Sometimes we really would like to have one of those, although we now have better methods for looking into the future. For example, we study many papers and attend conferences all over the world. ThyssenKrupp Steel Europe's six trend scouts focus intensively on their specialist areas and try to gauge what will happen there in the next 5-15 years. This is the timeframe that we need, as a steel manufacturer, in order to respond promptly to impending changes – for instance, to develop new products and to protect our ideas with patents.

What does a trend researcher's everyday routine look like?

Christina Mendelin: As a steel company, we are affected by many external influences. For this reason, we have divided the world around us into ten "scouting fields" geared to our value chain, ranging from basic materials and production technologies to market and environmental changes. Each trend scout constantly monitors academic papers and online media in his or her field and uses conferences and trade shows to establish contact with outside experts.

Marcus Rauhut: Internally, we exchange views regularly at our weekly editorial meetings, at which each trend scout can put forward new topics and we then decide together how to take them forward. In many cases, we obtain feedback from our colleagues, who have a lot of know-how in many areas – for instance, in basic materials, surfaces, chemistry, and steel processing.

Padberg: Alongside this network of internal and external experts, our customers also play an extremely important part. We listen to them very carefully, to find out what they expect of us in the future. We want to know, for example, what the requirements will be for new materials for our customers' future products.

"WE ARE DRIVING FUNDAMENTAL INNOVATIONS IN COLLABORATION WITH PARTNERS"
DR. LOTHAR PATBERG

What part do cooperation arrangements play in your work?

Padberg: These are becoming more and more important for us. Especially with hybrid materials, major manufacturers have to work together on development in order to drive fundamental innovations. ThyssenKrupp Steel Europe collaborates here, for example, with plastics manufacturers and automobile producers. However, the management of such cooperation arrangements is a very complex task – and, in the future, it is this that will separate successful companies from those that are less successful.

Regarding materials, is it really possible to make such a long-established material as steel even better?

Padberg: With steel, we are actually far from the end of the development process. In the future, we are expecting not only further improvement but also radical innovations, such as steels that can perform specific functions. Such a material could, for example, change shape at a given temperature and thus, to a certain extent, "switch". To do this, we intend to make use of the different structures in steel that can be activated deliberately by the influence of heat.

Mendelin: Lightweight construction will be another important area in the future – for example, in ⇢

Engineers and technicians work in the **applications hall** on new solutions.

relation to mobility. Sandwich materials could have a significant part to play here. For this reason, we are currently developing materials made up of different layers, which combine the benefits of, for example, steel and carbon fibers – for instance, with one layer of carbon fiber reinforced plastic embedded between two top layers of steel. In this way, we could produce hybrid materials made up of a wide variety of different types.

“OUR CUSTOMERS EXPECT TAILORED SERVICES AND SOLUTIONS”

DR. MARCUS RAUHUT

Rauhut: Such intelligent materials are also what our customers are expecting from us. In the future, it will not be enough to offer them only steel and nothing else: They will expect additional service, plus solutions tailored to their products.

It is always hard to make long-term forecasts. Are there any past examples where trend researchers have hit the bullseye?

Padberg: There certainly are! For example, we at ThyssenKrupp Steel Europe identified the trend toward material-saving lightweight construction at a very early stage. Back in 2004, we launched the “New Steel Body” project and showed how it is possible to use steel efficiently and to provide greater stability for thin-walled components by means of profiles. Ten years ago, these were trendsetting ideas, but nowadays we see a lot of these things in automobiles. This is because material-saving construction is resource-friendly and an excellent response to the megatrend of lightweight construction.

Mendelin: There are other examples, too. Our work has also dealt from the outset with boosting the output of wind turbines, and in the past three and a half years we have developed a concept for onshore repowering.

Padberg: That’s right. First we asked our customers what they wanted, and one thing quickly became clear: They wanted to achieve better yields through higher towers. Then we used our expertise in steel application and processing to develop a new concept for the cost-effective production of wind towers. In the future, it will be possible to manufacture them with a high level of automation by using spiral welded pipes. It is planned to build a prototype as early as next year, and the first of these towers could come onto the market in 2016.

Does your work always result in a prototype?

Padberg: We examine the technical and economic feasibility of our concepts. As soon as we have completed the first prototypes, we hand the projects over to our colleagues in production development. However, they are already involved as early as the evaluation stage, because we want to give them only those ideas that they will be able subsequently to put into practice. In our work, we are always on the lookout for possible show-stoppers – in this way, we avoid expensive production developments that do not lead ultimately to a marketable product.

What major trends are going to influence ThyssenKrupp most strongly in the coming decades?

Mendelin: Mobility is on the verge of a great upheaval. Alternative drives, in the form of electric and hybrid vehicles, will be more and more important in the future, although it is still too early for any expert to know exactly how the market will develop. In addition, there is the trend toward at least partially automated driving, which is likely to change mobility from 2020 or 2025. Finally, there are also changes in the social framework: More and more people are accepting carsharing and doing without a car of their own. Such developments are of interest to our company, because the automotive industry is a major customer of ours.

Rauhut: The concept “Industry 4.0” is likely to become very important in the future. The increasing integration of the manufacturing process will enable us to improve production and material flows further. ThyssenKrupp Steel Europe produces many millions of tons of steel every year, so we naturally wonder which developments in this field will be transferrable to our steel mills.

Finally, how do you think the world will look 20 years from now?

Padberg: We expect a fundamental change in mobility, especially in cities and in the world of work: Certain routine activities will be changed by digitization, and the need for more highly skilled activities and a considerable degree of flexibility will grow further.

“SANDWICH MATERIALS WILL PLAY A SIGNIFICANT PART IN THE FUTURE”

CHRISTINA MENDELIN

Mendelin: Generative manufacturing processes will have a big part to play. We are already seeing a boom today in 3D printers for plastics. In theory, this is also possible for metallic materials: It would then be possible to have many precision components, such as clock gears, printed instead of producing them by cutting.

Rauhut: In 20 years it will be more important to people to know exactly what they are buying. They will pay attention, for example, to how much energy has been used in making products, or they will ask for information about the recycling of goods. At some point, this could even be a crucial factor in their purchasing decisions.

Sarah Feil is actually studying biotechnology at Braunschweig University of Technology. Shock absorbers were something with which she had first to familiarize herself.

A female perspective

How can shock absorbers be made more sustainable in future? Nineteen female students have been looking into this issue on behalf of ThyssenKrupp Bilstein. The project was part of the Innovation Workshop, an initiative launched by Femtec to promote women in science and technology.

TEXT: ALEXANDRA GROSSMANN
PHOTOS: CHRISTOPH OTTO

Sarah Feil found it difficult at first to delve into the topic of sustainable shock absorbers. “I had dealt with sustainability a little in the past – but I had very little experience of it,” reports the 24-year-old student of biotechnology at the Technische Universität Braunschweig. “Shock absorbers were completely new to me, and at the start of the project I had real reservations because it is a very technical subject”.

The project was part of Berlin-based Femtec GmbH’s career-building program, which is organized every two years. Female students learn together in “schools” how to improve their management and leadership skills – such as their ability to work in a team and to motivate other members of staff. The program also includes the Innovation Workshop: In cooperation with partner companies such as ThyssenKrupp, the female students are set a specific task on a current technical topic. In this case it was: What can be done to improve the sustainability of shock absorber production at ThyssenKrupp Bilstein? ⇢

"This is a practical challenge we are currently facing, because our customers are placing ever higher demands on the sustainability of products," explains Dr. Andreas Rohde, who supervised the project for ThyssenKrupp Bilstein. "They are focusing chiefly on environmental performance, compatibility, and of course the cost-effectiveness of our innovations." It was therefore increasingly important to take these aspects into account early on in the development process, this being the only way to ensure that the subsequent products are actually sustainable: "That means that at the very start of the process we have to stipulate which criteria we are considering and plan to implement."

These very criteria were at the heart of the Femtec project: Sarah Feil and her 18 colleagues were to draw up a list of requirements for the production of the new shock absorber. The team was diverse: alongside a few budding mechanical engineers, students of mathematics, business studies, and waste management were also represented. "At our kickoff meeting the students still looked quite puzzled – they were simply unsure whether they were up to it," recalls Rohde. "The topic was not only very abstract but also very extensive. However, following an initial meeting in March and a few conference calls I saw that they were equal to the task."

The future biotechnologist Feil also had to enter uncharted territory for the project. "At the start there was a very good presentation on the topic," she recalls. "Then we had some time to read up on the topic a little – and then it started." Feil took charge of project management, assisted by her deputy Malena Schulz from ETH Zürich. "The most difficult thing was coordinating the 19 participants, because there was always someone who was not free at a particular time," says Schulz, who is studying mechanical engineering. Each of the female students was, after all, engrossed in their own studies, exams, and work placements at the same time.

Nonetheless, the team tackled the task very professionally. The young women met up with their project manager only three times over the three-month period: at the kickoff meeting, for an interim assessment, and for the final presentation. Everything else was handled over long distances and electronically. "I can only admire how well the students organized their activities," praises Rohde. "They made dozens of phone calls and more than 500 emails were exchanged."

Exchange of experience with other players

He recalls many open debates and the special approach to a number of tasks adopted by the young women. "On the issue of recyclability, for instance, men might have researched how to create a recycling-friendly product," reports Rohde. "In contrast, the female students proposed talking to staff from a recycling firm. I found this interpersonal aspect and the exchange of experience with other players interesting."

The project also provided its participants with new experiences. "If you are studying a technical subject, you are always surrounded by men," says Schulz. "The proportion of women studying mechanical engineering is about ten percent, for example. With Femtec it was rather strange suddenly to find yourself in a group of 19 young women."

The result of the Femtec project is a questionnaire containing 30 points, which is intended to cast light on the topic of sustainability in the future development of shock absorbers from various angles and in a structured manner. The students first subdivided the complex issue into various categories, such as material, process, and innovation. Other points concern the life span of a shock absorber, such as the period of use or end of useful life. The number of questions per category varies between two and eight. The respondents can either check preset answers or provide longer responses in a separate field.

A section of general questions, for example, deals with whether customers have already asked about the sustainability of the product, and whether the relevant data are available at all. Even the respondents' assessment forms part of the list of questions: do you consider your own product to be sustainable? Some questions are more general in nature – for instance, the authors want to know whether the readers have further ideas on the topic of sustainability. They also touch on whether alternative materials could be used to reduce noise pollution during the product's service life, or whether the water in the production process can be recycled. The students also question the use of crude oil: can this precious raw material be replaced altogether with pneumatic cushioning in the shock absorber? Or could vegetable oil at least be used instead of crude oil?

The big moment in the program then arrived in mid-June: several team members presented the project's findings at ThyssenKrupp. "The final event was certainly exciting," reports Schulz. "At the start you don't know what kind of feedback to expect. Moreover, a presentation to an audience of proffessionals is always daunting. But everything went well, and we received a very positive reception – we were proud of that." The group was highly praised, for example, for its thorough analysis and its special approach to a hitherto unknown topic.

The students' findings will certainly not be disappearing into a drawer somewhere. "For us this is a very real project," stresses Rohde, adding, "It is now all about implementing the results of the questionnaire at the company." The next step will be for ThyssenKrupp Bilstein's developers to examine the students' suggestions – and take them into account in their future development projects.

"IT WAS RATHER STRANGE SUDDENLY TO FIND YOURSELF IN A GROUP OF 19 YOUNG WOMEN."

MALENA SCHULZ

A successful team: Susann Liedtke, Sarah Feil, Yilin Yu, Malena Schulz, Franziska Rudisch, Susanne Lang, Lena Mengel, and Caroline Matthis (from left) at the end of the project in June.

Targeted promotion of women

Femtec is an initiative backed by the Technische Universität Berlin (TU Berlin) and the European Academy for Women in Politics and Business (EAF). It seeks to develop networks and has been promoting women in the natural sciences and technology since 2001. Its aim is to get young people interested in engineering and science, to improve their career prospects, and to interlink science and business. To that end the initiative has established links with major international technology companies such as ABB, Daimler, Airbus, and ThyssenKrupp. In addition, Femtec is working with Germany's nine leading universities of technology (also known as TU9), such as TU Darmstadt and RWTH Aachen University, as well as with the Swiss Federal Institute of Technology Zürich (ETH Zürich). The female students go on excursions, visit production facilities, and thus also come into contact with potential employers.

ThyssenKrupp also promotes women in many ways – its diversity@thyssenkrupp initiative aims to support greater diversity across the Group. This includes efforts to increase the percentage of women through targeted measures: The company intends to bring the proportion of women in senior positions up to 15 percent by 2020. Sponsoring and seminars at the ThyssenKrupp Academy are some of the activities involved. Women are also being targeted in the recruitment process – as is also demonstrated by the cooperation with Femtec.

App from Atlanta

ThyssenKrupp maintains some 90 research centers around the world, where international teams work on new solutions and products. One example is the US university Georgia Tech, which focuses on the latest developments in the field of elevator technologies. This is part one of a series introducing the ThyssenKrupp research centers.

TEXT: JOST BURGER

How can the energy consumption of elevators be reduced? Where else is it possible to save space? What materials will make the cab lighter? And when will apps be used for elevators? These are questions that are being tackled by the nine engineers – men and women – at the ThyssenKrupp Elevator Research Innovation Center (RIC). Their mission is to discover innovative solutions for all aspects of modern elevator technology and to make them market-ready. The RIC is part of the global network of ThyssenKrupp Tech Centers, which are driving innovation in their respective technological fields. This team, established in early 2013, is based in an ideal setting: at the heart of the Georgia Institute of Technology campus in Atlanta.

Georgia Tech is one of the top places in the USA for bringing together scientific expertise, technical innovation, and the American pioneering spirit. The ThyssenKrupp team works at Tech Square, which is home to the offices of private-sector cooperation partners and a business incubator with several hundred startups. Forty of these are operating in the very same building as the elevator experts. "We interact on our projects with these startups," says Thomas Felis, who heads the Tech Center. "We have also concluded a research agreement with Georgia Tech, which enables us to carry out projects with every department in the university."

These are perfect conditions for a fruitful culture of innovation. This culture is also evident as soon as you take a look around the rooms in the Tech Center. There is a display cabinet containing machine parts and models from a 3D printer. Toward the window front, some offices are separated by glass partitions with semi-transparent acetate sheets attached to them, covered from top to bottom with sketches and handwritten formulae. If you look very closely, you will notice unusual things even on the desks: for example, a UFO-like object, which turns out to be a holographic mirror and part of a project for a new type of human-machine interface. The open-plan office is dominated by a group of sofas, where the team comes together to think about not just elevator innovations but also new business models.

Similar diversity is to be found in the group of engineers. Apart from the German Thomas Felis, it is composed entirely of Americans, supplemented by interns from all over the world. "Here, we bring together the talent and skill of design, software, and electrical engineers. This gives us a broad base on which to develop and adopt new ideas, examine them for practicability and, ultimately, make them into products," says Felis. If the group members decide that an idea is interesting, they get down to work: each one does research in his or her own specialist field, individual problems are thought through, and analyses are carried out. The aim is always to pursue an idea right through to market-readiness. "We look at new technologies, develop a possible concept for putting them into effect, and present this to the Group," Felis explains. "The combined expertise of engineers and technicians then helps to turn our concept into a product."

The ThyssenKrupp team in Atlanta: Shima Bahri, Tre Watts, Thomas Felis, Lindsey Warren, Shawn Park, and Dawn Duvall (from left).

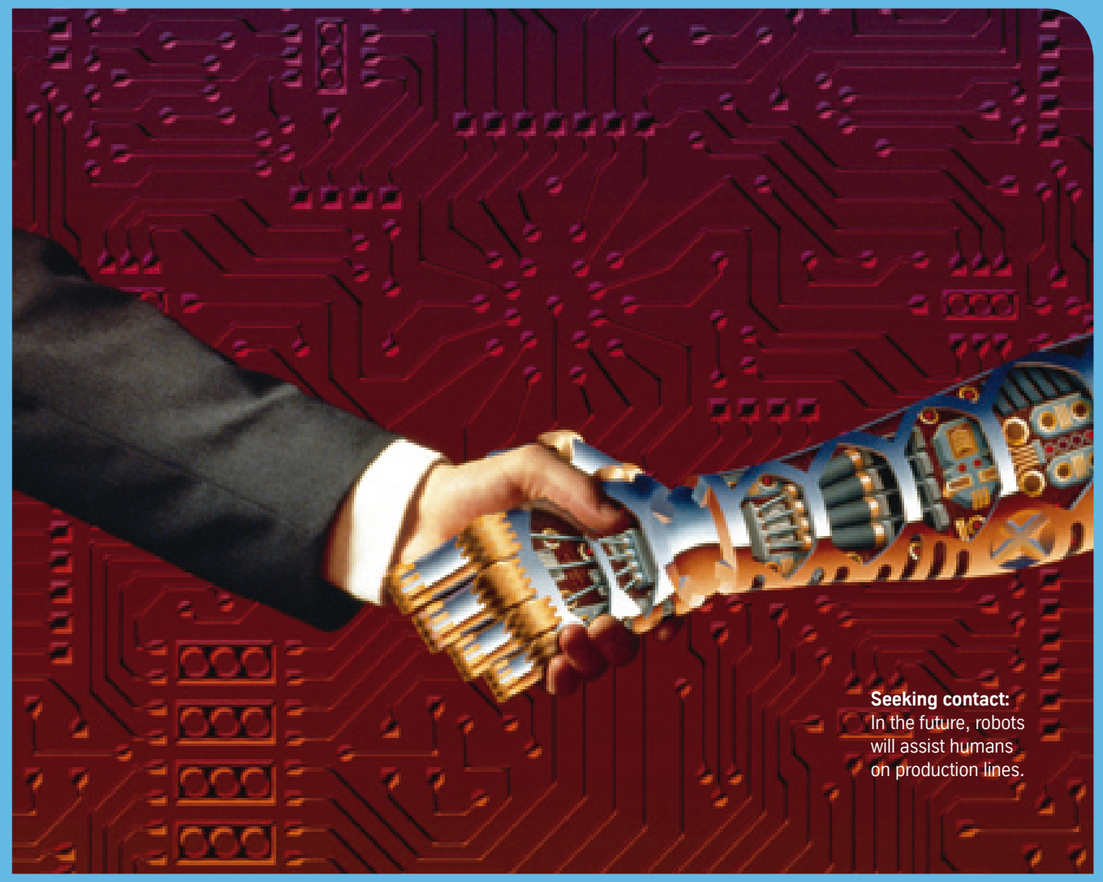
Lattice framework for elevators

This generates solutions which, for example, help colleagues in the sales and service sectors to meet their customers' requirements better. One of these is an interactive brochure. At a meeting with a customer, the ThyssenKrupp employee lays a smartphone or a tablet computer on a particular place, such as an image or a technical description. An app created at the Tech Center identifies what is there and conjures up a three-dimensional representation of the machine part on the screen. "This app is already being put to practical use," Felis reports. "We developed it in collaboration with a startup that has its office two floors below us."

Lightweight materials made from graphene and composite materials are another current subject of research in elevator construction. The engineers can use them to develop energy-saving products, which can also be manufactured at low cost. For this reason, the Tech Center team is working on components that are lightweight but still extremely stable. To achieve this, they construct load-bearing components that are largely hollow but have a kind of internal lattice framework: this absorbs forces that have been calculated beforehand in simulations. They can then immediately use 3D printers to turn their ideas into models, which form the basis for the production of full-scale prototypes. "In the end, these components have the exact required degree of stiffness at the load points, with the smallest quantity of materials and minimum weight," Felis explains. "We are conducting this research project in collaboration with the Georgia Tech Manufacturing Institute."

The team is also well connected within ThyssenKrupp. "We collaborate mainly with the other global research and development centers in the elevator field," Felis reports. The Tech Center also works with other parts of the Group, such as Resource Technology and the ThyssenKrupp Tech Center in Dresden. For both the elevator sector and the Group as a whole, regular meetings are held to promote a global exchange of experience. These are also a stage for presenting interesting new products for the Group. Who knows? In a few years' time, perhaps it will be one of the innovative ideas from Atlanta that will take us up to the top of a skyscraper.

Temporary storage device for renewable energies
The Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) in Ulm has commissioned ThyssenKrupp System Engineering to plan and construct a fully automated pilot facility for the formation of lithium ion battery cells. In the formation process, the cell is, for the first time, discharged under precisely controlled conditions at different tensions and current strengths – a decisive process for its quality. The facility will initially have 240 formatting stations and is due to enter operation at the end of 2014. The system is so flexible that it will be possible at a later stage to increase its capacity by a further 240 stations.



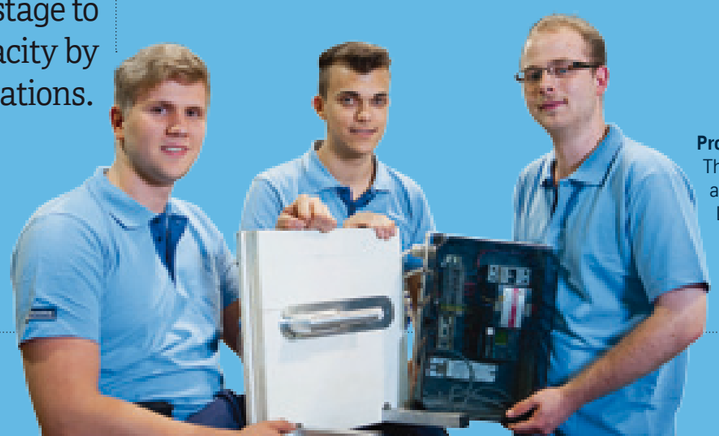
Seeking contact: In the future, robots will assist humans on production lines.

Working hand in hand with ROBOTS

Humans and machines become colleagues.

Workers and robots still stay out of each other's way at factories – the mighty machines are placed behind barriers, so that they cannot injure anybody. This is expected to change in the future: In the "InSa" research project, ThyssenKrupp System Engineering is working with the University of Bremen Center for Computing and Communication Technologies (TZI), the Bremen Institute of Industrial Technology (Bremer Institut für Produktion und Logistik, BIBA), S-GARD, and the IT company neusta mobile solutions to develop solutions for effective collaboration between humans and robots on industrial production lines.The idea is that intelligent robots will interact with a sensor system integrated into the workers' protective clothing, which will function like an aura to ensure that they keep a safe distance. This is a major challenge: "The robot will need to recognize a worker and immediately stop or take evasive action," reports Dr. Eckhard Wellbrock, project leader for ThyssenKrupp System Engineering. "The robot's control cycle has just 20 milliseconds to do this." The prototypes are being trialed in a realistic test environment at ThyssenKrupp System Engineering GmbH. The German Federal Ministry for Economic Affairs and Energy has given around €2.2 million to support the project.

Apprentices shine at "Young Researchers" contest
First place in the Dortmund, Duisburg, and Saarbrücken regional contests was won in each case by a different team of ThyssenKrupp apprentices. Another two teams came second and third in the Duisburg regional contest. At the "Young Researchers" contest ("Jugend forscht"), participants compete for the top spot in seven specialist fields. The ThyssenKrupp apprentices shone in the technology and working world areas. The ThyssenKrupp Steel Europe team, for example, presented a door handle which disinfects itself without the need for chemicals. ThyssenKrupp has been supporting Germany's best-known young researchers' contest for many years and is sponsor of the regional contests in the Saarland and North Rhine-Westphalia.



Proud winners: The Dortmund apprentices Tim Leubecher, Lukas Latassek, and Kay Musielak at the regional contest.

Test rig for world's biggest fusion reactor
ThyssenKrupp Schulte has made a major contribution to the construction of the International Thermonuclear Experimental Reactor (ITER). Its Munich branch has designed a test rig for its customer, KRP-Mechatec Engineering, which is intended to provide information on the load capacity and mechanical stability of the moving supports for the ITER vacuum vessel. "The vacuum vessel, which weighs around 10,000 metric tons, is one of the most important components of the nuclear fusion reactor," says Andreas Kellermann, manager of the Munich branch. To enable the vessel to expand during the fusion process and absorb the magnetic forces generated, it rests on nine moving steel supports. These have to withstand a weight comparable to that of the Eiffel Tower. The test rig resembles a gigantic vise: The model support can be clamped inside the structure and tested for stability using hydraulic equipment.

A beauty contest for heaters

The switch to renewables is a complex project – as our columnist **Peter Glaser** found out when he tried to change to a sustainable heating system.

One thing was clear: We needed a new heating system. Our old oil burner dated back to the 1970s, and its controls always reminded me of trips to a drive-in movie theater, because the speakers that you get there for your car have only two settings: Too loud or too quiet. We had the same problem: We either sweated as if in a sauna or froze as if in Siberia.

And so we needed a modern, sustainable replacement. After my wife and I had read the internet dry, we set our hearts on pellet heating with condensing technology. Powered by wood, a renewable raw material and cheaper than oil. A modern burner, which retrieves the lost heat that used to escape through the chimney. More expensive to buy, admittedly, but more economical in the long run and more environmentally friendly. A perfect plan.

That is, until one day we happened to think about how we would actually get the pellets delivered to us in the second courtyard. We live in an old coach house, and fuel-oil lorry drivers have to bring an 80-meter hose with them specially in order to refuel us. Pellets are similarly blown in through a hose, but this one can be only half that length. Otherwise, all that comes out will be sawdust. Fixated on pellets, I hunted for another solution. In my mind's eye, I saw workmen dragging 20-kilogram sacks full of little pieces of wood. So much for the price saving. Then, though, we did manage to find a supplier with a narrow transporter that would fit through the entrance to our yard. It was going to work after all!

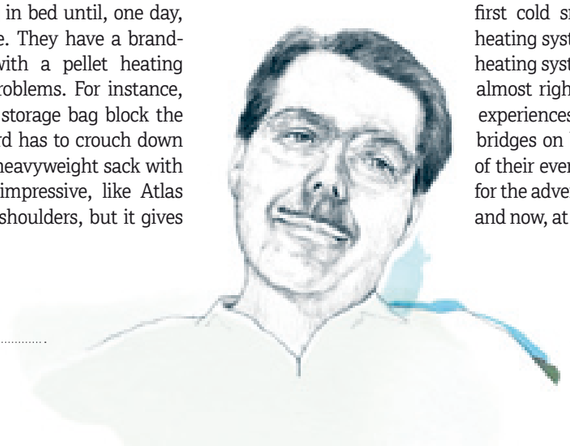
But not quite – for below the yard there is an underground garage, and nobody knew whether its roof would take the transporter's weight. Every night, I exhausted my own sleepless, renewable energy tossing and turning in bed until, one day, friends invited us for coffee. They have a brand-new low-energy house, with a pellet heating system – and no end of problems. For instance, when the pellets from the storage bag block the screw conveyor, the landlord has to crouch down underneath and move the heavyweight sack with his shoulders. This looks impressive, like Atlas loading the Earth onto his shoulders, but it gives you a bad back in the long run. Perhaps pellet heating was not such a good idea. Anyway, it would be much more efficient to run the modern condensing technology on gas than on wood. What is more, modern gas boilers are small enough to hang on the wall. This would give us a whole extra room, which is currently still occupied by the oil tank – and we would not need to have either oil or pellets delivered in the future. Heating problem solved.

Almost, that is, because – as with the pellets – there was one small problem: How would we get a gas connection from the road to the second yard? It would be necessary to dig on land belonging to two owners' associations. If just one of the 60 owners were to say no, that would be the end of the project. But could it be that our neighbor who lives 10 meters away has gas in his house? Then we would need only his agreement. Yes – there was gas in the rear building. And yes – the owner was willing to let us take our gas from there. The plan was on again!

And so, we agreed a contract with a gas supplier. Then there was just one more tiny formality to complete: The right of way for the gas pipe. Strictly speaking, it needed to be recorded in the land register, but the neighbor did not want that. "Three sentences will be enough." Between friends. And so, we formulated those three sentences, and then – well, then things became tricky. It seemed to me like trying to swim in a pool full of honey. At night, I dreamed of extremely slow-moving beauty contests for heaters, with charming gas boilers. Gradually, it dawned on me that the neighbor had said yes while meaning no. It came to the middle of August, we could sense the approach of fall in the air – and still we had no heating. We thanked him politely and said we had changed our mind after all. Our relationship has turned somewhat cooler now.

In my hour of need, I called our favorite plumber, a man on whom I can rely when the first cold snap is imminent and I need a new heating system in a hurry – and an oil condensing heating system, at that. And so, this means we are almost right back where we started – but many experiences richer. Some people have to jump off bridges on bungee cords to escape the sameness of their everyday life. We, instead, let ourselves in for the adventure that is the switch to renewables – and now, at long last, we are back in the warm.

Peter Glaser is an author and journalist. He writes for publications including the Neue Zürcher Zeitung and Technology Review. He won the Ingeborg Bachmann Prize in 2002.



Value creation of the future

What profound technological, economic, and social changes are to be expected by 2030 and what impact are they likely to have on the value chain and jobs in Germany? Experts from the BDI working group on Innovation Strategies Geared to Value Creation have explored such issues for this study.

DEUTSCHLAND 2030 (GERMANY 2030)
Federation of German Industries (BDI)
Free of charge at www.bdi.eu/Publikationen.htm

Diagnosis and treatment

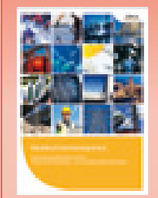
In this book two of Germany's most well-known climatologists delve into climate change and its consequences. They start with an overview of climate history, explaining what lessons we can learn from that for our current situation. Yet they do not confine themselves to a mere diagnosis – at the end of the book they put forward specific proposals for tackling the problem of climate change.

DER KLIMAWANDEL (CLIMATE CHANGE)
Stefan Rahmstorf, Hans Joachim Schellnhuber
(C.H. Beck) €7.99

First-class introduction

From the basics of the energy debate to biomass fuels and trends in battery research to electricity from nuclear fusion: In this book renowned researchers from the Max Planck Society examine the many facets of the complex topic of energy. Apart from scientific issues they also deal with the political and economic framework for future developments in this field. Even though the book sets out its arguments eruditely, the individual articles are easily accessible and written in a lively style – it is therefore no surprise that *Die Zukunft der Energie* (The Future of Energy) even years after its publication still offers a first-class introduction to the energy debate. Anyone who has read the book can follow the current discussions with ease.

DIE ZUKUNFT DER ENERGIE (THE FUTURE OF ENERGY)
Peter Gruss, Ferdi Schüth
(C.H. Beck) €16.90



Guide for companies

The switch to sustainable energy can succeed only if we adapt our power consumption in future to the available supply of renewable energies. The *Handbuch Lastmanagement* (Load Management Handbook) reveals the potential for intelligent load management lying dormant in companies and why this new flexibility will pay off – through revenue from shiftable loads, for instance. Practical examples and tips on the gradual introduction of load management round off this dena publication.

HANDBUCH LASTMANAGEMENT (LOAD MANAGEMENT HANDBOOK)
German Energy Agency (dena) €19.50

IMPRINT

PUBLISHED BY:
ThyssenKrupp AG, Corporate Function Communications, ThyssenKrupp Allee 1, 45143 Essen, Germany
RESPONSIBLE EDITOR:
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PUBLISHING HOUSE:
Axel Springer SE Corporate Solutions
PROJECT MANAGER: Christopher Brott
EDITOR-IN-CHIEF: Christian Buck
ART DIRECTION: Christian Hruschka & Stefan Semrau (twotype design)
PICTURE EDITING: Bianca Classen
PRINTED BY: Neef & Stumme premium printing GmbH & Co. KG
Schillerstrasse 2,
29378 Wittingen, Germany
ISSN: 1612-2771

PHOTO CREDITS

THYSSEN KRUPP: pp. 4-5, 6-7, 15, 18, 24, 26-29, 30-31, 37, 45, 46-47, 48-49.
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“Our future energy system must be intelligent and flexible – then we can combine environmental sustainability with economic and social sustainability”.

Ever since his student days at RWTH Aachen University **Dr. Friedrich Löser** has been inspired by the topic of energy – which later on also played a key role in his work on the Transrapid project. Now the Head of ThyssenKrupp’s TechCenter Control Technology in Munich is again a technological trailblazer: Through cross energy management he is helping to ensure that our power grids continue to operate stably. **Page 20**