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FRAUNHOFER INSTITUTE FOR MACHINE TOOLS AND FORMING TECHNOLOGY IWU

E³-FORSCHUNGSFABRIK RESOURCE EFFICIENT PRODUCTION

E³ FORSCHUNGS FABRIK

E³: RETHINKING INDUSTRIAL PRODUCTION

Industrial production is what makes Germany a prime investment target. But, overarching strategies and technological applications are called for not only to keep it competitive, but at the cutting edge of innovation. For instance, resources have to be organized more sustainably, energy has to be saved, material has to be better exploited and scarce raw materials have to be recycled more efficiently. This is the reason why the E³-Forschungsfabrik Resource-Efficient Production at the Fraunhofer Institute for Machine Tools and Forming Technology IWU applies its E³ strategy to come up with solutions to these pivotal challenges and link them together synergetically.

The demographic development, the increasing desire for individualization, the changing need for mobility or the role people have to play in an increasingly automated production are challenges that we have to measure up to on the way to the production processes of the future. Industry 4.0, one of the crucial projects in Germany's hi-tech strategy, has the purpose of progressively interlinking the real and the virtual worlds. Scientists at Fraunhofer IWU go beyond just coming up with individual projects to compete in production and high technology sites: they rethink industrial production itself.

The focus on "resources" will have sustainable implications on the production of tomorrow. It engenders evolving products, technologies, production systems and new approaches to operating productive companies. This is where Fraunhofer IWU puts itself in position for launching integrative ideas that are poised for the future and transformed into competitive products. They are generated in factories that are energy- and resource-efficient and are working on low emissions. And people are located in the center of things as the creative problem-solvers and process managers.

The idea behind all of this is applying integrated analysis to researching how flows of materials, energy and information can be planned and linked to each other in a more efficient way. State-of-the-art production sites transform specific solutions for factory and production levels. Integrative ideas take advantage of synergies making all production processes increasingly flexible. All of this will consume significantly less energy and resources than previously while maintaining the same or an even higher level of output and makes better analysis and planning possible.

With the E³ strategy to the production of the future

The E³ strategy is formulated at the Fraunhofer Institute for Machine Tools and Forming Technology IWU. It sets the levels of analyzing technologies, systems, logistics and factory processes in a new analytical/methodical context, including the role of people in future production processes. Our mission statement of "maximum real net output at minimum levels of resources" places the development of technologies and processes in the center of attention. It builds on energy- and resource-efficient production technologies, new factory strategies and new approaches to transforming the role people have to play in production into a competitive advantage for German industry. The three "E's" stand for three levels of research where scientists will be jointly transforming their vision of the production of the future into practical applications with their partners in industry: saving energy and resources by coming up with new machines, technologies and strategies for solving the problems of emissions-neutral factories coupled with a new way to integrate people into production. This reorientation applies, exploits and launches synergies to tap into new avenues for solving pivotal challenges in production technology.

FIGURE *Campus E³ production of the Fraunhofer IWU in Chemnitz, Germany*

Fraunhofer lighthouse project "E³ Production"

The E³ strategy was integrated in Fraunhofer's lighthouse project "E³ Production" in November of 2013. Lighthouse projects are large-scale overarching projects where several Fraunhofer institutes merge their capabilities to work at ways to solve problems affecting society as a whole. A total of twelve Fraunhofer institutes from the areas of production, materials, components, light & surfaces, information and communication technologies and life sciences pool their talents in the lighthouse project. Demonstrators and pilot applications will be formulated by 2016 at four sites in Germany. These will serve the purpose of transforming ideas into reality more speedily while heightening awareness among key branches of industry for our ideas and findings. Not only the Fraunhofer Institute for Machine Tools and Forming Technology IWU, but also the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart, the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund and the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin will be showcasing holistic concepts from the Fraunhofer lighthouse project "E³ Production".

From vision to competitive advantage

The "E³-Forschungsfabrik Resource-Efficient Production" was unveiled as one of these demonstrators at Fraunhofer IWU in spring of 2014. On more than 1,600 square meters, new centers of technology, production techniques and factory planning strategies are being researched for energy- and resource-efficient production in the three competence areas of "Powertrain", "Car Body Manufacturing" and "Data and Energy Management 2.0". Then they are field-tested in joint collaboration with our industrial partners. The E³-Forschungsfabrik acts as a vehicle for research and development where pilot projects and applications are field-tested in joint collaboration with industrial partners and being demonstrated to the public. Here, the analysis of process chains is writ large. This is the reason why it is only a holistic analysis of individual processes, upstream and downstream steps in the process and quality and logistic processes that make it possible to capture complex interactions within an overall process chain. This is not just theory. It is real hands-on work approaching actual production conditions. This is a new quality of interaction between industry and research because ideas can be transformed into hands-on applications faster.

Facts and figures

– construction period: June of 2011 (laying the cornerstone) to November of 2013 (handing over the building)
– basic shop area: 1,640 square meters
– output readings: block-type thermal power station (200 KW electrical, 300 kW thermal), photovoltaic system (60 kW), refrigerating capacity (360 kW process refrigeration and 360 kW climate refrigeration)
– 160 measuring points for recording approximately 1,500 readings
– the generator and consumer can capture, exploit and visualize all of the flows of resources (such as electrical energy or compressed air)
– in addition, the main components of process control technique (block-type thermal power station, photovoltaic system and the main electrical feed) feed data into a central information system
– data is captured with IWU's Linked Factory software at a high level of temporal resolution
– mobile or stationary receivers can be localized with a built-in WLAN-GPS system and data can be provided for each site

What people have got to say about the E3-Forschungsfabrik Resource-Efficient Production:

Prof. Dirk Landgrebe, Executive Director of the Fraunhofer IWU:
"Fraunhofer IWU has been joining forces with the regional economy and scientific institutions such as the Technische Universität Chemnitz and others for more than 20 years to come up with new ideas for German production technology. The E³-Forschungsfabrik means that we actively join forces with all parties involved to link up to the historical tradition and identity of the Chemnitz research location as a powerhouse for cutting edge production technologies. We use our world of ideas for the factory of the future to display today in experiments and demonstrations how research, learning and production will be tomorrow."

Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft:
"We use our E³ factory to speed up the process of transforming technologies and processes into real-life practice while raising awareness in German industry for new potential solutions to the problem of sustainable production. This is where tests can be made in ongoing production operations to discover how machines and processes have to be set up for the resource-efficient production of tomorrow."

Prof. Johanna Wanka, Federal German Minister for Education and Research:
"The German Ministry of Education and Research provided 15 million euros of funding for the InnoCaT® innovation alliance. Now that funding has run out, scientists are continuing the fruitful relationships they established with their business partners from industry to link up to findings and research priorities. I'm glad our research funding has given impetus to work that is still felt today. The issues the Fraunhofer-Gesellschaft and its business partners are pursuing are of major importance for the future because resource-efficient production will become increasingly important – I'm convinced of that."

Stanislaw Tillich, Prime Minister of the Free State of Saxony:
"The new E³ factory demonstrates how much more real industrial net output can be created with significantly less energy, material and waste. That makes good business sense for sustainable management while giving the domestic industry an important competitive advantage."

Prof. Hubert Waltl, member of the managing board of AUDI AG, production and the chairperson of the board of trustees of Fraunhofer IWU:
"Today, the vision is a factory that is digitally interconnected throughout so that machines communicate with one another autonomously and even repair themselves. We want to use the E³-Forschungsfabrik to transform this into reality step by step. As a model for production sites, it is not only used for scientists to formulate strategies focused on the future resource-efficient and emission-neutral factory. They can also test it out under real-life conditions. That makes it important for the entire Volkswagen corporation in terms of our business strategy – along with the other partners in this project."

1 *The festive opening of the E³-Forschungsfabrik took place on May 15, 2014.*
2 *Prof. Reimund Neugebauer, Prof. Johanna Wanka, Stanislaw Tillich and Prof. Hubert Waltl (from left to right) dedicate the area of engineering excellence for car body engineering.*

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Powertrain

NEW TECHNOLOGIES AND ENHANCED-QUALITY PRODUCTS

The focus of the area of engineering excellence for the powertrain is designing and creating ultrashort process chains based on forming. This enables scientists to decrease energy utilization, material consumption and the duration of processes by substituting manufacturing and machining processes with more resource-efficient technologies or eliminating certain process steps altogether.

Innovation for the powertrain: rethinking the way gear shafts are manufactured

Fraunhofer IWU has carved out a leading role for itself in manufacturing rotationally symmetric components by forming technology. The weight of components can be reduced and material total eliminated using incremental forming processes. This especially includes spin extrusion, rotary swaging, axial forming and gear rolling.

Here, the focus is on developing holistic forming-based process chains ranging from technology-adapted component design through comparative component analysis with conventional processes right down to series production on the premises of the final customer. The powertrain area of engineering excellence lays the technical foundations for trying out these new ultrashort process chains under factory conditions. Within the scope of the Fraunhofer lighthouse project "E³ production", a complete process chain for the manufacturing of hollow gear shafts has been researched and developed as a demonstrator for the first time. These car gearbox hollow shafts are responsible for torque transmission in the powertrain. The conventional process chain includes the steps of forging, turning and drilling, hobbing, heat treatment, grinding, and shot peening. In the new process chain, expensive, material- and time consuming machining processes, such as drilling and hobbing, are replaced by resource-efficient forming processes, such as spin extrusion and gear tooth rolling. In addition to the optimization of the individual technologies and the production planning, new information management and factory planning tools are integrated into the process chain at the factory level and refined. The objective is to tailor a process chain that is cross-linked with the factory environment, completely supervised and optimized in terms of energy.

Formulating functionally microstructured surfaces can systematically impact certain facets such as tribology, sealing/joining technology and haptics and acoustics. Even the energy efficiency of machine tools is analyzed in all of its complexity. It is problematic to make any general statements without simultaneously analyzing the process and component. After all, developing the machine the workflow has to identify and operate the parameters that are pertinent to maintaining the machine properties for the required precision and criteria that contribute to efficient production. Therefore, new approaches in the plant design will also be stepped up.

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FIGURE *More efficient process chains by combining innovative manufacturing technologies and intelligent data and resource management*

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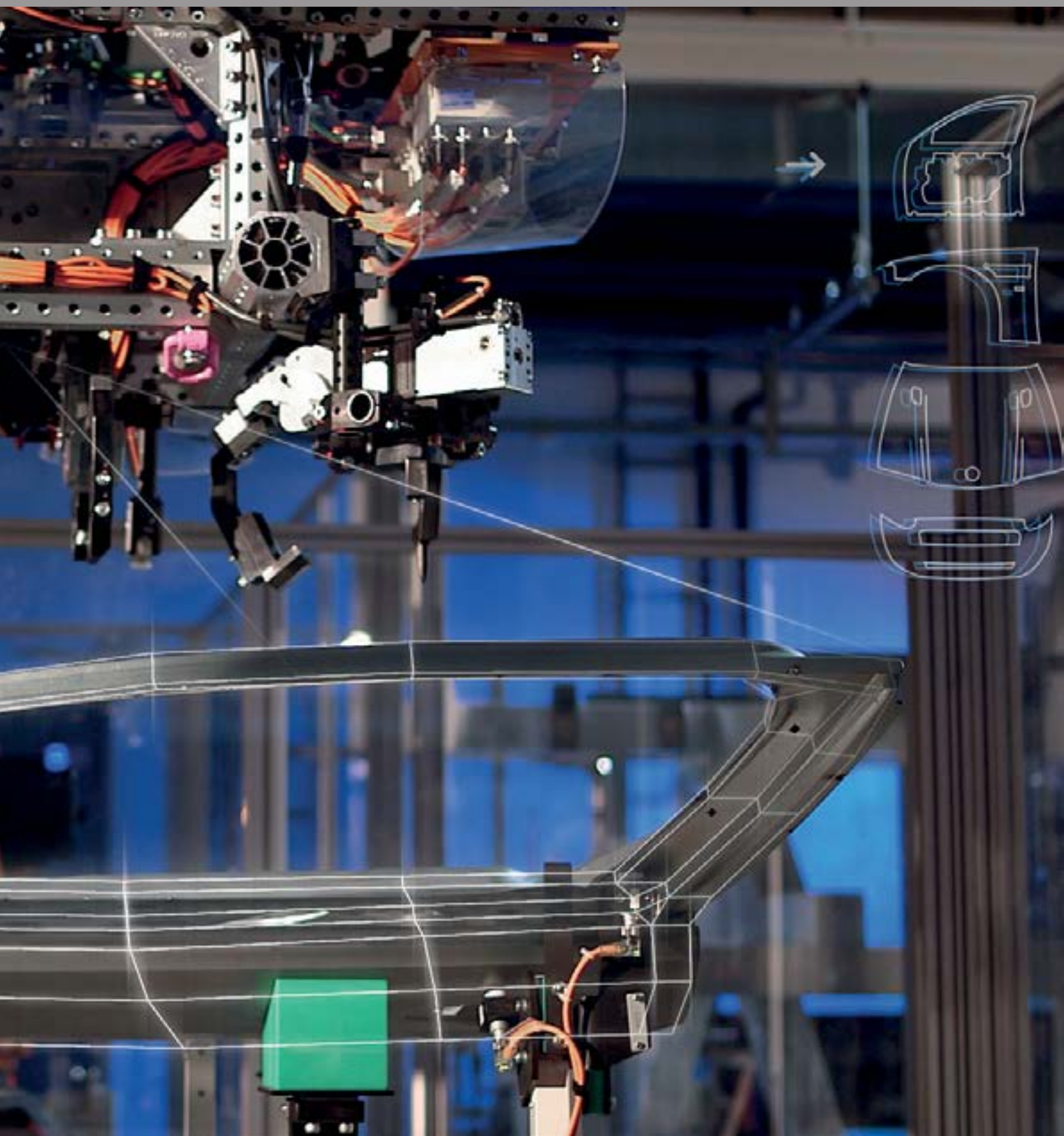
Car Body Engineering



FLEXIBLE PRODUCTION SYSTEMS

The focus of the field of competence for car body engineering is the future of car manufacturing. The demand for energy- and resource-efficient mobility including the burgeoning variety of models call for new and advanced developments in car body engineering that are on track for the future.

Car body engineering 4.0 – flexible, modular and interconnected

More and more customers are looking for individualization, creating a booming demand for model versatility combined with shorter product life cycles in the car industry. On the one hand, to meet the demands of the market, highly complex production capacities have to be quickly engineered for new and modified car models. On the other hand, the car industry targets uninterrupted capacity utilization of its factories at sites all over the world. Here, fluctuating markets are a major challenge. This is the reason why the car body manufacturing field of competence builds customized products for devices including handling, joining and quality systems.

By using a duplicate system with identical reference processes for assembling car doors, Fraunhofer IWU puts its heads together with German OE partners to do near-series research and tests on new technologies under realistic production conditions. These scientists have a vision: using in-line measuring equipment, mechanized clamping devices and intelligent software-based assistance systems to make self-regulating car body engineering possible. This could produce various customized and individualized models on a production line in the medium-term. Finally, cutting edge quality control circuits would be available in the try-out stage as a basis for flexible and adaptive car body engineering systems.

State-of-the-art measuring and testing technology facilitate the analysis and testing of recently developed operating materials or components used in car body manufacturing as well as final assembly such as clamping devices, grippers, tools and subassemblies. Another essential focus of research revolves around the role played by people in industrial production in the future. Some challenges emerge from the demographic development, unrelenting automation and the new opportunities arising offered by information and communication technologies. Pivotal issues are new strategies for man-machine cooperation and production environments adapted to an older workforce.

The trend towards utilizing materials in pioneering strategies for car body engineering to save weight (and therefore fuel consumption) continues unabated. Reliable series production strategies are devised such as for press hardening to satisfy burgeoning present and future demands in terms of energy and resource efficiency.

FIGURE *One major goal: producing various individualized models on one production line*

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Data and Energy Management 2.0

DATA, RESOURCES AND REAL NET OUTPUT

The data and energy management 2.0 field of competence has a vision of the factory of the future with emission-enhanced production sites that have an active role to play in an increasingly volatile energy market. The steps in the production process have to be broken down into individual efficiency increments while holistically analyzing them to discover and exploit any potential for saving energy. This ranges from the individual process right through the process chain and onto the factory level.

The intelligent factory

A holistic analysis of and streamlining in the data and energy management 2.0 field of competence implies the availability and utility of information for all resources required such as flows of materials and energy in the factory. Simultaneously, the increasing interconnectedness between machines, systems engineering and logistic processes creates immense volumes of data and requirements of data storage in manufacturing companies while the IT systems used are becoming increasingly complex. That's not all; information has to be interlinked and brought together in a central location to speed up troubleshooting and streamline flows of materials and energy to specific machines and systems right down to the factory level and logistics processes. This is the reason why making the right information available at the right time, at the right place for the right purpose is an essential criterion for the value of these data. Putting this in context, the role people have to play in state-of-the-art production strategies in the data and energy management 2.0 field of competence is addressed in particular by research projects on "mobile IT". Putting it all together, there is a great deal of work underway focusing on solutions for mobile terminals such as data glasses, smart phones and tablets to handle the pertinent data from production and logistics and exploit them based upon context.

Energy development, resource management ideas, linking up state-of-the-art energy consumption prognoses, storage systems and new strategies for building technologies (using block-type thermal power stations, photovoltaic systems, heat exchangers and energy storage systems) will greatly drive down energy costs and emissions in factory operation. For instance, scientists are putting great efforts into the extent to which production capacity can follow the current energy supply, what capacity can be kept in various forms of energy, decentralized and central storage media and what parameters can be provided. In other words, production will transform itself from an energy consumer to an energy converter and storage medium. This will not only make it more robust against external volatility. It will also generate new business models to make a proactive contribution towards a more flexible energy market.

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FIGURE *The right information, at the right time, at the right place: Fraunhofer IWU creates solutions for the context-based providing of information in the production and factory environment.*

SUSTAINABILITY AS A DRIVER OF INNOVATION

An interview with Prof. Dr.-Ing. Matthias Putz, the project manager of the Fraunhofer lighthouse project "E³ Production"

The E³ strategy emerged at Fraunhofer IWU and it was introduced the first time in 2011 by Prof. Reimund Neugebauer, the director of Fraunhofer IWU at that time. What is the difference between this approach and other strategies such as industry 4.0 or the smart factory?

Industry 4.0 stands for the interconnectedness of data and production technology while linking state-of-the-art information and communication technology with manufacturing technologies. The smart factory takes advantage of this development while transmitting it to the factory level: the idea behind it is self-sufficient production processes and self-streamlining and communicating machines and systems. The E³ strategy incorporates these single solutions and expands their horizon. Instead of competing for the fastest and highest-level technology for industry 4.0, we avail ourselves of E³ as a new method for searching for integrative innovations. These new approaches and types of analysis have the purpose of helping us to pinpoint potentials and synergies while interlinking Fraunhofer IWU's capabilities even more efficiently.

Skyrocketing energy prices, international competition and limited resources: how can E³ help German production techniques and in particular German technologies and products continue to provide the cornerstone for real net output in future, thus guaranteeing prosperity in our society?

Innovation is emblematic for keeping one step ahead of the competition: that's the point of departure for our research work and foremost paradigm for maintaining prosperity by real industrial net output in Germany. This is where the E³ strategy has to respond to agenda-setting global trends in development to guarantee that German production technology can not only maintain its competitive edge; we can also keep ahead of the others with new ideas. That's something we have done from the beginning with our business partners in industry. That's also one of the reasons why we are admired in Europe and the world for this close and extremely fruitful connectivity between industry and research. We want to use E³ here to apply and advance issues such as industry 4.0, the smart factory – or Fraunhofer IWU's core topic, energy- and resource-efficient production – to forge it to an efficient philosophy of innovation.

In November 2013, the E³ strategy was integrated into Fraunhofer's lighthouse project "E³ Production" that twelve Fraunhofer institutes are involved in. What does that mean for the standing of Germany's production technology and what impact does it have on Fraunhofer IWU?

There's no doubt that the Fraunhofer-Gesellschaft has a leading role to play in production research. On the one hand, the launch of the E³ lighthouse project production evidences the fact that the issue of future production has transformed itself into a challenge involving the whole of society. This is the reason why Fraunhofer wants to expand on its claim to leadership. On the one hand, Fraunhofer IWU's position as a coordinator in this lighthouse project is recognition of our project and core competencies. On the other hand, this function enables us to boost the visibility of our research work beyond the area of our immediate activities, which involves great responsibilities for our institute.

The lighthouse project is interdisciplinary – does production technology research have to provide still greater access to bordering realms of the science? Where do you see the added value for the future?

Interlinking is an important component of our lighthouse project. Along with the seven member institutes in the Fraunhofer Group for Production, there are also another five institutes involved such as from material technology, information and communication technology and process engineering. Furthermore, there is a wide range of projects where issues from conventional production research with approaches from other sciences can be synergetically linked to

potential solutions. Interdisciplinary work is not unknown to our institute. For instance, we already have a series of win-win links to mathematics, business management or even the social sciences in joint work with the Technische Universität Chemnitz in the Saxon Cluster of Excellence eniPROD® to solve problems with production technology challenges.

The E³-Forschungsfabrik Resource-Efficient Production has been launched in May of 2014. What makes the E³-Forschungsfabrik in Chemnitz, Germany a research factory of the future for German production technology?

One of the prime reasons we chose the term research factory was because we don't work under laboratory conditions. Our new experimental field is closer to a factory than a laboratory because it offers the opportunity to research with industrial equipment on an industrial scale. To be sure, there are other institutes in Germany that delve into production of the future. However, what's special about our Chemnitz research factory is first of all the fact that we concentrate on two fields of technology arising from the core competencies of our institute, they can continue to and do indeed make their mark there: car body engineering and the powertrain. Secondly, our E³-Forschungsfabrik is a symbol for the way we can work with industry in co-operative partnerships for ideas such as how a new and contemporary form of interaction can be established between science and industry. We have been successful at involving research and development into our E³-Forschungsfabrik with and for large-scale companies that do not have their headquarters in Saxony. This also boosts the attractiveness of Chemnitz as an investment target. This is where our many years of trusting research partnership with large-scale car companies pays off. This collaborative atmosphere has aroused the interest of suppliers and equippers to join forces with us in the factory of the future beyond this classical commissioned research. It's not a question of excluding companies from Saxony. We want to entice new partners with the regional industry using our partnership as a launching pad and support linking.

How should the E³ factory be ranked in the lighthouse project?

In the lighthouse project, we intend to bring the findings into focus at four demonstrator sites. This will not only include Chemnitz, but also Berlin, Stuttgart and Dortmund. We will be placing the main emphasis on technology-oriented issues in our E³-Forschungsfabrik, in particular in creating ultrashort process chains for powertrain components. Another object of study is energy and research management on the factory level. Finally, we are researching ways to open up new options for people's design capabilities in the production of the future.

How is the Technische Universität Chemnitz involved with the E³-Forschungsfabrik?

The E³ strategy and our formidable expertise on issues of energy- and resource-efficient production are putting a lot of trust in joint research projects such as eniPROD® and the fundamental university research it builds upon. We want to be more efficient at exploiting these synergy effects and testing new forms of co-operative relations with industrial partners, including training up-and-coming scientists in MINT profiles.

How can the E³-Forschungsfabrik help raise awareness among various industries for new ideas in technology and joint projects?

Our E³-Forschungsfabrik is a flexible open-access platform for the co-operative relationship we are always aiming for, especially with small and medium-sized companies that do not have any or only limited resources for their own research and development. Our research factory provides a realm where technical innovations, new frontiers and modern ideas can be tested – and what's very important: we can demonstrate to industry the feasibility and profitably of new technologies and processes in close proximity to real-time practice.

How might the subjects pursued by your research factory look like in ten years?

That is a very difficult question to answer. After all, as a Fraunhofer Institute, the hallmark of our research work is a high level of application-orientation and timeliness. In other words, it has to be possible to transform ideas into practical applications as quickly as possible. Of course, that does not mean that we do not devote ourselves to medium- to long-term issues in our E³ strategy. This is the reason why the technical equipment in our E³-Forschungsfabrik is extremely flexible and provides a realm and the opportunities for a wide range of still unanswered questions for practical applications. Beyond this, in my opinion, the content of our research will advance along our foremost core competencies. We will be putting more effort into subjects such as interlinking technology and machines.

Instead of single-track solutions, our future thinking will have to be more extensive in terms of systems where lightweight construction with new materials and material processes such as joining and assembly engineering will have a major role to play. The trend towards more flexible and individualized production will open doors to additive processes – not least at our institute. On the factory level, there will be additional ideas emerging from the frontiers provided by information and communication technology and the new opportunities of providing and storing energy. With the E³-Forschungsfabrik, we will definitely be able to more easily deal with the complexity and requirements made of burgeoning individualization and flexibility in production technology. I firmly believe that our approaches to innovation will still be of value in ten years. ■

The E³-Forschungsfabrik Resource-Efficient Production

The vision
Each of the three "E's" stand for the three levels of research in our E³ strategy: saving energy and resources by coming up with new machines and technologies, ideas for emission-neutral factories and giving impetus for getting people involved in the overall production processes.

What's new
The E³ strategy places the levels of analyzing technologies and systems of logistics and factory processes and from involving people into production into a new analytical/methodical context.

What's special about our project
We generate surplus value by applying, exploiting and launching synergies of the three "E's".

www.e3-fabrik.de/en

1 *The data on all of the resources needed including the machine and process data converge on the factory level in the management center.*

Imprint
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