Fraunhofer

ANNUAL REPORT 2017

THE FUTURE OF WORK

Fraunhofer-Gesellschaft

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. The majority of the more than 25 000 staff are qualified scientists and engineers, who work with an annual research budget of 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Around 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787 – 1826), the illustrious Munich researcher, inventor and entrepreneur.

Figures as at January 2018.
www.fraunhofer.de

ANNUAL REPORT 2017
THE FUTURE OF WORK

Ladies and gentlemen,

2017 has been a year of profound change, both in politics and society, and in business and research. Amidst it all, Fraunhofer continues to operate as a dynamic and forward-looking organization, constantly seeking to maintain and promote research and innovation as a pillar of Germany's and Europe's economic strength. Our focus is directed as always toward applied research, which we now pursue through innovative forms of collaboration that deliver excellence, efficiency and results as never before.

We grew once more in 2017. Today, more than 25,000 employees work across Germany in Fraunhofer's 72 institutes and research institutions, and in its national and international subsidiaries, with a total budget of 2.3 billion euros. These figures are proof that our research and development activities are catering admirably to current market needs.

In order to build on our position as one of the world-leading R&D organizations long term, we intend to engage fully with new realities and new developments. This includes the digitalization of industry, research and society – a huge undertaking both in its transformative potential and in its complexity and dynamism. In order to exploit such opportunities to their full potential, the Executive Board has drawn up the Fraunhofer 2022 Agenda, which is split into the action areas of research, transfer, good business management and digitalization. A section of this annual report is devoted to this topic.

By implementing the Agenda, we seek to further improve the quality and synergy of our work, to build on what sets us apart as a connected innovator with efficient research and transfer structures and thus to increase our appeal to contract research customers.

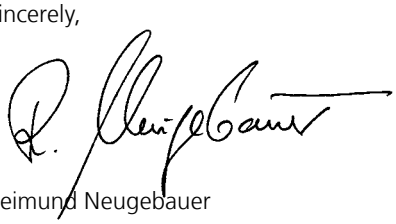
We can expect digital and biological transformation to have a greater and greater impact on the entire world of work. Basic jobs will continue to disappear, replaced by a greater number of challenging, creative and responsibility-laden roles. One of the key articles in our annual report looks at precisely these developments.

At Fraunhofer, too, the way we work is changing. It is a basic truth that an organization's success depends in large part on the knowledge, experience and commitment of its people, and nowhere is this more evident than in a research organization. Accordingly, we are doing all we can to attract and retain the best specialist and management personnel, aiming for a diverse balance of people across our operations. That is why we offer family-friendly working models as well as challenging and self-regulated work.

In order to be at the forefront to shape any developments and potential disruptions, we are also placing increasing importance on monitoring and forward-looking socio-economic research. To this end, last year we established the Fraunhofer Group for Innovation Research – INNOVATION, which coordinates the work of five Fraunhhofer Institutes. We expect these to become even more active in a political advisory role as time goes on.

Allow me to join with my fellow Executive Board members in extending a warm thanks to all our customers, contractors, and to governmental policy-makers for continuing to place their trust in us; fulfilling your highest expectations is our ongoing goal. I would also like to extend a sincere thank you to our employees for their commitment and first-class work – it is thanks to you that Fraunhofer enjoys such high regard in the research, business and political spheres.

Sincerely,



Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

REPORT OF THE EXECUTIVE BOARD

REVIEW OF FRAUNHOFER RESEARCH

FINANCIAL REPORT

SERVICE

REPORT OF THE EXECUTIVE BOARD

THE EXECUTIVE BOARD

Reimund Neugebauer is Professor of Machine Tools at the Technische Universität Chemnitz (TU Chemnitz). After leadership roles in the mechanical engineering industry, in 1991 he set up what is now the Fraunhofer Institute for Machine Tools and Forming Technology IWU, which grew to become an international center for manufacturing engineering in his 21 years of service as its director. He has been President of the Fraunhofer-Gesellschaft since 2012.

Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult. Dr. h. c. mult.
Reimund Neugebauer
President of the Fraunhofer-Gesellschaft, Corporate Policy and Research Management

Andreas Meuer has occupied a variety of leading roles at Fraunhofer-Gesellschaft headquarters since 1992, most recently as Director of Finance, Accounting and Business Planning. He became a member of the Executive Board at the beginning of 2018.

Dipl.-Kfm.
Andreas Meuer
Executive Vice President, Controlling and Digital Business Processes

The Executive Board

After studying to become a lawyer, Alexander Kurz worked as a manager and board member for major research organizations such as CERN in Geneva and the Karlsruhe Institute of Technology (KIT). He has been a member of the Executive Board of the Fraunhofer-Gesellschaft since 2011.

Prof. Dr. rer. publ. ass. iur.
Alexander Kurz
Executive Vice President Human Resources, Legal Affairs and IP Management

Georg Rosenfeld holds a doctorate in physics. After working as a research scientist at the Forschungszentrum Jülich and at the University of Twente in the Netherlands, he joined the Fraunhofer-Gesellschaft as Division Director Corporate Development and then as Division Director Research. The Senate appointed him to the Executive Board in 2016.

Prof. Dr. rer. nat.
Georg Rosenfeld
Executive Vice President, Technology Marketing and Business Models

MANAGEMENT REPORT 2017

Fraunhofer-Gesellschaft – key data for 2017 (in € million)

	2016	**2017**	Change	
Business volume by segment	**2081**	**2286**	**+205**	**+10 %**
Contract research	1879	1992	+113	+6 %
Defense research	114	121	+7	+6 %
Major infrastructure capital expenditure	88	173	+85	+97 %
Business volume by budget	**2081**	**2286**	**+205**	**+10 %**
Operating budget	1853	1940	+87	+5 %
of which: personnel expenses	1193	1260	+67	+6 %
of which: non-personnel expenses	619	640	+21	+3 %
of which: change in reserves [1]	41	40	–1	–2 %
Capital expenditure budget [2]	228	346	+118	+52 %
Project revenue by segment	**1451**	**1596**	**+145**	**+10 %**
Contract research	1386	1466	+80	+6 %
of which: industrial revenue	682	711	+29	+4 %
of which: public-sector revenue [3]	704	755	+51	+7 %
Defense research	49	57	+8	+16 %
Major infrastructure capital expenditure	16	73	+57	+356 %
International revenue [4]	304	**311**	+7	+2 %
Patent applications (number)	608	**602**	–6	–1 %
Employees (number)	24,458	**25,327**	+869	+4 %

1 Change in special license-fee revenue reserve.

2 Current capital expenditure on contract and defense research as well as major infrastructure capital expenditure.

3 Includes German federal and state governments, EU and other revenue.

4 Includes international subsidiaries' project revenue generated with third parties; excludes license-fee revenue.

STRATEGY AND OPERATING ENVIRONMENT

Profile of the Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. (Fraunhofer) is a non-profit organization that was founded in 1949 and has its headquarters in Munich. It carries out applied research and development (R&D) for the benefit of business and society. By directing the focus of its work toward the key technologies of the future, the Fraunhofer-Gesellschaft plays a central role in the innovation process, in both Germany and Europe.

Fraunhofer maintains 72 Fraunhofer Institutes and Research Institutions across Germany. The majority of the some 25,000 people who work for Fraunhofer are qualified scientists and engineers. Together they generate an annual business volume of €2.3 billion, almost €2.0 billion of which relates to **contract research**. Around 70 percent of Fraunhofer's contract research revenue is derived from contracts with industry and publicly funded research projects, while about 30 percent of Fraunhofer's budget is accounted for by base funding provided by the German Federal Ministry of Education and Research (BMBF) and the state governments in a ratio of 90 : 10.

Seven Fraunhofer Institutes address topics that fall within the sphere of interest of the German Federal Ministry of Defence (BMVg). These activities, which are financed in full by the BMVg, are grouped together under **defense research**. Capital expenditure on construction and infrastructure projects, including the initial cost of equipment for new institute buildings, is recognized as a separate accounting item: **major infrastructure capital expenditure**.

Each Fraunhofer Institute develops its own market orientation and core competences on the basis of its immediate market environment and its links with the scientific community. Although the institutes operate as separate profit centers, they are not autonomous legal entities.

The eight **Fraunhofer Groups** are a way for Fraunhofer Institutes with related areas of technological expertise to coordinate their R&D strategies:

- Innovation Research – INNOVATION (since 2017)
- Information and Communication Technology
- Life Sciences
- Light & Surfaces
- Materials and Components – MATERIALS
- Microelectronics
- Production
  and
- Defense and Security VVS

In addition, institutes or departments of institutes with different core competencies work together in **Fraunhofer Alliances** in order to develop and market solutions for specific business sectors.

At an organization-wide level, Fraunhofer identifies fields of enterprise and innovative technologies with significant market potential and sets up in-house research programs to move them forward.

The Fraunhofer-Gesellschaft offers its **employees** the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institutes, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects for a career in industry by virtue of the practical training and experience they acquire.

At an **international** level, subsidiaries and representative offices as well as partnerships with other top-class research organizations and innovative companies ensure Fraunhofer direct access to the key regions of present and future scientific progress and economic development.

Strategic initiatives

Fraunhofer aims to find the best responses to new challenges, whether they concern the increasing complexity of globally networked value chains or the digital transformation taking place in many areas of industry and society. That is why the organization's Executive Board has drawn up a detailed roadmap. Called the **Fraunhofer 2022 Agenda**, its purpose is to make clear to employees and stakeholders alike the change processes currently considered essential at Fraunhofer and the corresponding projects put in place to implement them.

The Fraunhofer 2022 Agenda draws on the vision expressed in the new Fraunhofer Guiding Principles, namely to implement initiatives of systemic importance to Germany as an industrial hub. That is why Fraunhofer is intensifying the cross-institute development of system solutions in the seven areas of strategic importance known as Fraunhofer's **Key Strategic Initiatives**:

- Battery technology
- Biological transformation
- Cognitive systems / data sovereignty
- Programmable materials
- Public safety and security
- Quantum technology
- Translational medicine

The goals of these initiatives are either to achieve a leadership position in science, to generate significant industrial revenue or to raise social awareness of the topic in question. In order to make maximum use of the potential synergies of cross-institute collaboration when pursuing the Key Strategic Initiatives, it is necessary to adapt not only Fraunhofer's research and transfer structures, but also its internal methods of thematic research and project management.

The purpose of the new **Fraunhofer Clusters of Excellence** is to put in place a cross-cutting structure that enables institutes to develop and address systemically important issues in a collaborative manner. In organizational terms, these research clusters function like a virtual institute spread across several locations. They are not temporary structures, focusing merely on a temporary individual project, but follow a roadmap that sets out the long-term evolution of a complex technological trend. The Clusters of Excellence are helping Fraunhofer become a leader in key areas of research, such as advanced photon sources, programmable materials and immune-mediated diseases.

Fraunhofer's 17 **High-Performance Centers** are being evolved so, after carrying out an effective evaluation, they can develop and implement transfer roadmaps together with their university and non-university partners, and with local companies (particularly SMEs). These roadmaps will address all transfer paths, from contract research, licensing and spin-offs through to further-training courses and knowledge transfer. As of 2018, Fraunhofer will utilize its network of High-Performance Centers to establish a long-term national transfer infrastructure. Fraunhofer is working closely with the host states and industrial partners to finance the pilot phases. In the longer term, it is hoped that the federal government will grant additional funds, for instance as part of the Joint Initiative for Research and Innovation.

As a leading research organization, Fraunhofer is driving the global trend toward **digitalization** in many different application areas. For this reason, as part of its 2022 Agenda, Fraunhofer is digitalizing its own data stocks more thoroughly. Fraunhofer's administrative and research data will be interlinked, aggregated and analyzed in order to optimize the organization's R&D processes and to support management decisions, at the level of the individual institutes and that of headquarters. In particular, this will enable Fraunhofer to make collaboration between its institutes more efficient and, beyond that, to generate new business models for data utilization on behalf of third parties.

Spin-offs are a key transfer path in Germany's success as a driver of innovation. In 2017, for instance, the number of spin-offs rose once again, to 25. Fraunhofer intends to continue enhancing its ability to create spin-offs going forward. That also includes being the only research organization to participate in the third incarnation of Germany's High-Tech Gründerfonds (HTGF), a public-private partnership that provides seed capital for high-tech start-ups making it much easier for Fraunhofer spin-offs to gain access to German investors. In addition, Fraunhofer is evolving its funding formats for founders and stepping up its collaboration with external start-ups.

International activities and partnerships with R&D organizations across the globe have long been standard at Fraunhofer. They have developed into a complex network of direct commissions, consortium projects, strategic partnerships and independent Fraunhofer subsidiaries – one that requires constant recalibration to ensure its alignment with Fraunhofer's objectives. To this end, Fraunhofer is currently updating its proven strategy of internationalization so as to ensure that its international activities are more closely geared to its main topics of interest and can be developed in a targeted manner. By expanding its strategy, Fraunhofer intends to address topics such as mobility, partnerships with developing and emerging economies, and greater utilization of the potential synergies offered by the international Fraunhofer network.

New Executive Vice President, Controlling and Digital Business Processes

A new member was appointed to the Executive Board of the Fraunhofer-Gesellschaft as of January 1, 2018. After 15 years of service, Prof. (Univ. Stellenbosch) Dr. Alfred Gossner stepped down as Executive Board member with responsibility for Finance, Controlling and IT on December 31, 2017. Fraunhofer wishes to thank Alfred Gossner for his many years of hard work and for the decisive contribution he made to the success of the organization.

The members of the Fraunhofer Senate voted unanimously to appoint Andreas Meuer as Alfred Gossner's successor. Meuer, who holds a university degree in business management, will take on responsibility for Controlling and Digital Business Processes. He has been with Fraunhofer since 1992, during which time he has held a variety of management positions. Until recently, he was in charge of finance, accounting and business planning.

The new designation for Andreas Meuer's Executive Board function reflects its altered focus. The strategic goal of the **Fraunhofer Digital** project, which is assigned to this function and forms part of Fraunhofer's 2022 Agenda, is to make Fraunhofer's digital administrative regime the most efficient among all research organizations. Existing IT structures are to be adapted to the ever-changing environment so as to create added value for the institutes, the objective being to automate routine administrative processes and use AI-based assistance systems to support more complex issues. This will lighten the load on all concerned, freeing up resources that can be directed, in particular, toward quality assurance, the processing of complex issues, and meeting specific customer requirements.

Structural growth

Fraunhofer is continuously developing its research portfolio, tapping into new technological trends not only through its existing institutes, but also by integrating external research institutions and setting up new project groups, some of which ultimately become new Fraunhofer Institutes in their own right. In 2017, a start was made on integrating two external research institutions and establishing two new Fraunhofer Institutes and one Fraunhofer Research Institution. As a result, Fraunhofer has been operating a total of **72 Fraunhofer Institutes and Research Institutions** since the start of 2018.

Since January 1, 2018, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE has been working in Kassel on the transformation of energy supply systems and on addressing the technical and economic challenges they face. Until 2017, Fraunhofer IEE was a very successful branch of the Fraunhofer Institute for Wind Energy and Energy System Technology IWES. Located in Bremerhaven, Fraunhofer IWES will continue conducting research in the future, but under the slightly amended name of Fraunhofer Institute for Wind Energy Systems IWES.

Established on January 1, 2018, the Fraunhofer Institute for Microengineering and Microsystems IMM is the first independent Fraunhofer Institute to be set up in Mainz. Formerly known as Institut für Mikrotechnik Mainz GmbH, it was incorporated into the Fraunhofer-Gesellschaft in 2013 and was previously a branch of the Fraunhofer Institute for Chemical Technology ICT. A building extension commenced in 2017 will enable the Fraunhofer IMM to further enhance its expertise in its area of specialization – applied microstructure technology and microfluidics.

On January 1, 2018, LZN Laser Zentrum Nord GmbH and parts of the Institute of Laser and System Technologies (iLAS) of the Hamburg University of Technology were integrated into Fraunhofer and rebranded the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT, the first independent Fraunhofer entity to be established in Hamburg. Above all, Fraunhofer IAPT focuses on laser technologies, including highly innovative 3D printing techniques for a wide variety of industrial applications.

As of January 1, 2018, Fraunhofer absorbed Centrum für Angewandte Nanotechnologie CAN GmbH, another Hamburg-based enterprise. Given its research focus on quantum dots, OLEDs and biofunctional nanoparticles, and its expertise in nanoparticle synthesis by means of fluid reaction, CAN was integrated in the Fraunhofer Institute for Applied Polymer Research IAP and became its new site in Hamburg.

The newly established **Fraunhofer Group for Innovation Research – INNOVATION**, of which five institutes are now members, began operations on July 1, 2017. Comprising Fraunhofer ISI, IAO, INT, IRB and IMW, it is the first non-technological Fraunhofer Group. Its portfolio of socioeconomic and sociotechnical research complements the activities of the seven other Fraunhofer Groups. In setting up this new group, the Fraunhofer-Gesellschaft intends to further expand its research into, and support for, innovation processes and the technological, economic and social parameters that influence them. One focus of the new group is on bolstering the Fraunhofer-Gesellschaft's role in the research, technology and innovation policy dialog with industry, government and society.

Science policy framework

At the **German federal elections** last fall, Fraunhofer positioned itself with its own policy recommendations and, beyond that, put forward joint positions on research and innovation policy that it had formulated with trade associations and other scientific organizations. Tax incentives for R&D services – from which companies collaborating with Fraunhofer could benefit, for example – are once again firmly on the political agenda. Ensuring that public-sector investment in science and research keeps pace with steadily rising costs remains a challenge.

The **High-Tech Forum**, which was chaired by Fraunhofer President Prof. Reimund Neugebauer and Stifterverband President Prof. Andreas Barner, presented its two final publications in 2017, successfully concluding its work at the end of the 18th federal legislature. At the High-Tech Strategy Conference held on May 16, 2017, the Forum presented German Federal Minister of Research Johanna Wanka with its Innovation Policy Guidelines along with the suggestions for implementation put forward by the specialist forums. In close cooperation with Stifterverband für die Deutsche Wissenschaft and the other members of the Forum, Fraunhofer was able to make a decisive contribution – in terms of both content and methods – to the consultations on innovation policy in Germany. For example, the High-Tech Forum gave birth to the Learning Systems platform and made numerous recommendations, e.g. concerning tax incentives for research grants and instruments for funding radical step-change innovations.

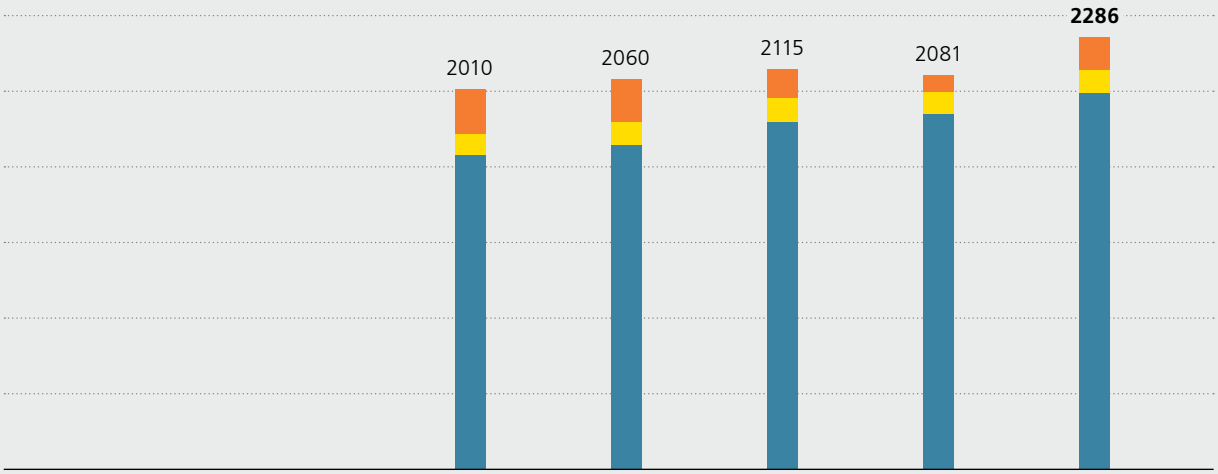
At the sixth and final meeting of the German government's **Innovation Dialog** in the 18th federal legislature, Chancellor Angela Merkel came together with representatives of business and science in June 2017. The meeting focused on Germany's role in a pan-European innovation policy. Using examples such as the digital transformation of the economy, cyber security and smart mobility, the participants discussed innovation policy action areas which, to a large extent, have to be tackled at the EU level and, if properly addressed, promise tangible added value for Germany and the other EU member states. The Innovation Dialog also addressed what are known as disruptive innovations. A dedicated working group came up with recommendations for instruments designed to enable step-change innovations and encourage trailblazing ideas. Fraunhofer President Prof. Reimund Neugebauer is a member of the steering committee. Through its involvement in the Innovation Dialog, Fraunhofer has exerted decisive influence on the choice and content of the topics – thus helping shape the political agenda.

In Brussels, deliberations on the **next EU Framework Programme** for research will soon get underway. They will not cover defense research, however, which will be given its own EU program in the future. Fraunhofer was one of the main drivers of this new program. Furthermore, initial proposals for the upcoming Ninth EU Framework Programme (FP9) contain key initiatives promoted by Fraunhofer, including, for example, ideas for a new European Innovation Council (EIC) and European "missions." Negotiations for the Framework Programme are set to last until at least spring 2019.

In its EU-related activities, Fraunhofer cooperates closely with the other members of the umbrella organization **EARTO** (European Association of Research and Technology Organisations), which is currently chaired by Prof. Frank Treppe, Director of International Affairs and Research Programs at the Fraunhofer-Gesellschaft. In March 2017, Fraunhofer organized EARTO's annual conference in Munich under the slogan "Shaping Europe's Future: RTOs at the Forefront of Innovation Supporting Industry." Together with more than 250 other delegates, high-caliber speakers from politics, the EU Commission, the German Federal Ministry of Education and Research (BMBF) and European research organizations discussed the future of European research policy.

Obtaining funding for education and research remained a key political objective last year. The budget of the BMBF rose to €17.6 billion in 2017, a year-over-year increase of 8 percent, and the Fraunhofer-Gesellschaft benefited from this growth too. Effective 2017, the German Bundestag approved an **increase** of €60 million in **base funding** from the federal government. The state governments agreed to the increase as well, contributing a further €7 million on the basis of the 90 : 10 funding ratio. With continuing strong growth in project revenue, the proportion of base funding in the Fraunhofer-Gesellschaft's budget had tended to decline in recent years. Now, it is back in line with the roughly one-third share envisaged in the Fraunhofer funding model.

The Fraunhofer-Gesellschaft's total business volume, in € million



	2013	2014	2015	2016	**2017**
Business volume by segment	**2010**	**2060**	**2115**	**2081**	**2286**
Contract research	1661	1716	1835	1879	1992
Defense research	114	118	127	114	121
Major infrastructure capital expenditure	235	226	153	88	173

Business volume by budget	**2010**	**2060**	**2115**	**2081**	**2286**
Operating budget	1590	1664	1783	1853	1940
of which: personnel expenses	1012	1093	1142	1193	1260
of which: non-personnel expenses	578	586	612	619	640
of which: change in reserves [1]		–15	29	41	40
Capital expenditure budget [2]	420	396	332	228	346

1 Change in special license-fee revenue reserve.

2 Current capital expenditure on contract and defense research as well as major infrastructure capital expenditure.

Total business volume

In business terms, 2017 was a very successful year for Fraunhofer. Compared with the prior year, business volume increased by 10 percent to €2286 million, with all three segments posting substantial growth. Contract research accounted for €1992 million, defense research for €121 million and major infrastructure capital expenditure for €173 million. Project revenue also rose by 10 percent. It totaled €1596 million across all segments and was a key contributor in financing growth. The development of the three segments will be discussed in greater detail in the following sections.

Business volume is based on the Fraunhofer-Gesellschaft's performance statement, which meets the requirements of the funding agencies and includes the operating budget and capital expenditure. In the operating budget, personnel and non-personnel expenses are recognized according to general accounting practice and the change in the special license-fee revenue reserve is disclosed as a separate item. As capital expenditure is recognized at the amount incurred at the time of purchase, depreciation, amortization and impairment losses are not included in the performance statement.

In 2017, capital expenditure accounted for a greater portion of business volume than in the previous year. With capital expenditure totaling €346 million, Fraunhofer invested 52 percent more year over year, marking a return to the high levels of earlier years. The personnel expenses recognized in the operating budget rose by 6 percent to €1260 million, an increase that was due to workforce growth of just under 900 employees (up 3.6 percent) and to a 2 percent wage increase granted under the collective wage agreement for the public sector. At €640 million, non-personnel expenses were around 3 percent higher year over year. The special license-fee revenue reserve increased by €40 million.

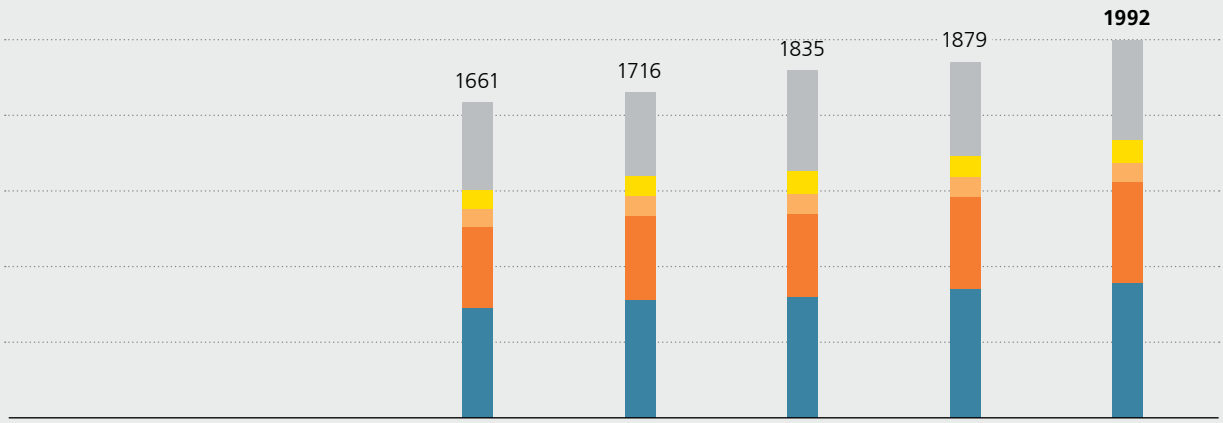
Contract research

Accounting for about 90 percent of business volume, contract research is the mainstay of the Fraunhofer-Gesellschaft's business activities. In accordance with the organization's mission statement, contract research includes research conducted on behalf of industrial and service enterprises, publicly funded projects and pre-competitive research financed with base funding. Base funding for the contract research segment is provided by the BMBF and the state governments in a ratio of 90 : 10. New project groups and research institutions generally receive initial funding from their host state during their first five years.

Budgeted expenditure for the contract research segment grew by 6 percent year over year to reach €1992 million in 2017. Of that total, the operating budget accounted for €1832 million, up 5 percent, and current capital expenditure for €160 million, up 24 percent. In line with Fraunhofer's funding model, two-thirds of budgeted expenditure is financed through project revenue, which rose at a similar rate to budgeted expenditure (up 6 percent), reaching €1466 million. Fraunhofer was able to post substantial increases in both contract research and public-sector projects as sources of project revenue.

Revenue from the EU was the only source of funds to record a steep decline in 2017. The reason for this decrease was that, for the first time, the funds stemmed mainly from the Horizon 2020 framework programme launched in 2014, and the annual budget set at the start of this programme was considerably lower than that of the previous framework programme. Nevertheless, Fraunhofer remains the third most successful organization in Europe when it comes to securing EU project funding – beaten only by CNRS of France and the Helmholtz Association, both much larger institutions.

Contract research: Revenue and budgeted expenditure, in € million



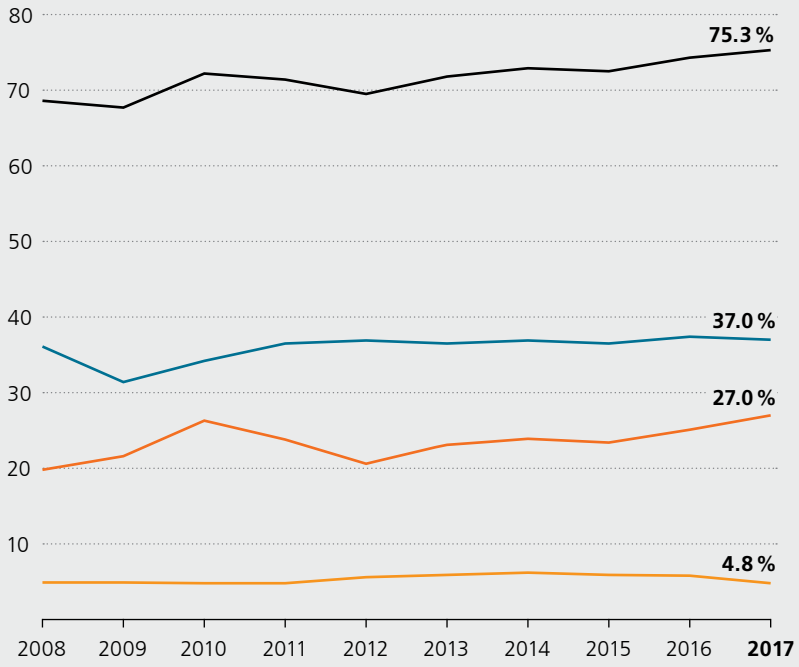
	2013	2014	2015	2016	**2017**
Revenue	**1661**	**1716**	**1835**	**1879**	**1992**
Total project revenue	1200	1272	1305	1386	1466
of which: industry	578	618	641	682	711
of which: federal and state governments	431	445	441	487	537
of which: EU	92	106	105	106	94
of which: other	99	103	118	111	124
Additional funding requirement (federal and state governments)	461	444	530	493	526
Budgeted expenditure	**1661**	**1716**	**1835**	**1879**	**1992**
Operating budget[1]	1494	1562	1675	1750	1832
Capital expenditure budget	167	154	160	129	160

1 Includes change in the special license-fee reserve (2017: €40 million, 2016: €41 million).

Industrial revenue thus rose by 4 percent overall to €711 million. Revenue from industrial and service enterprises, which Fraunhofer succeeded in growing by 5 percent, accounted for €568 million of the total. At €143 million, license-fee revenue matched the high figure of the previous year.

Revenue from project funding granted by the federal and state governments grew 10 percent, coming in at €537 million. This increase was due entirely to project funding from the German Federal Ministry of Education and Research (BMBF) and the German Federal Ministry of Economics and Energy (BMWi).

Contract research: Project funding ratio, in % [1]



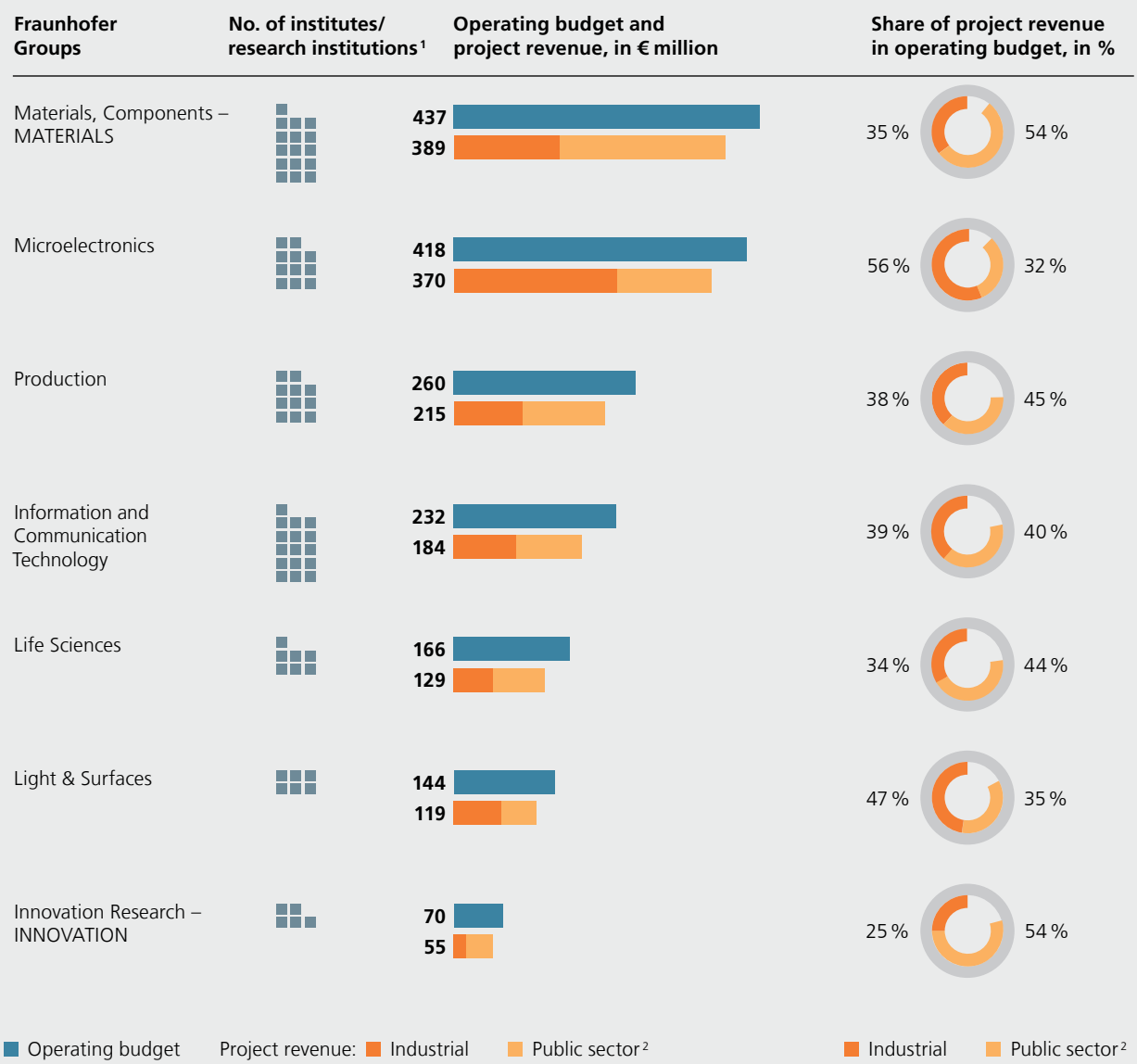
1 Proportion of operating budget covered by project revenue, including imputed depreciation of capital assets. Calculation excludes a) institutions still in the initial funding period and b) change in reserves.

2 Not shown in graph, 2017: 6.5%.

EU revenue decreased by 11 percent to €94 million, while other revenue grew by 12 percent to €124 million. An amount of €526 million in base funding from the federal and state governments was utilized to cover a shortfall in funds.

In line with the Fraunhofer-Gesellschaft's tried-and-tested funding model, the Fraunhofer Institutes must cover two-thirds of their budgeted expenditure from market sources. For this reason, the proportion of the operating budget (including imputed depreciation on capital assets) covered by project revenue and, in particular, the proportion covered by industrial revenue constitute key performance indicators for the contract research segment. In 2017, the proportion of the operating budget covered by project revenue was 75.3 percent, while the proportion covered by industrial revenue was 37.0 percent. Project funding from the federal and state governments accounted for 27.0 percent, EU revenue for 4.8 percent and other revenue for 6.5 percent. The long-term trend in the project funding ratio bears witness to the Fraunhofer Institutes' sustained success in contract research and project business.

Contract research: Performance statement of the Fraunhofer Groups 2017



1 As of January 1, 2018; includes contract research carried out by the seven defense-related Fraunhofer Institutes.

2 Comprises federal and state governments, EU and other revenue.

Contract research of the Fraunhofer Groups

In the contract research segment, the 72 Fraunhofer Institutes and Research Institutions collaborate in seven groups based on related areas of expertise. That also includes the contract research performed by the defense-related Fraunhofer Institutes, which are united in the Fraunhofer Group for Defense and Security VVS. The organization of institutes working in related areas into groups enables them to coordinate the procurement and utilization of strategic equipment, and to develop a common market image. The groups delivered steady performance in 2017, with a funding mix approaching the targets of the Fraunhofer funding model.

With an operating budget of €437 million, the Fraunhofer Group for Materials and Components – MATERIALS is Fraunhofer's largest group in business terms. It is closely followed by the Fraunhofer Group for Microelectronics, with an operating budget of €418 million. These two groups also occupy the top positions when it comes to the portion of their operating budgets (without depreciation of capital assets) covered by project revenue. Whereas 54 percent of the operating budget of the Fraunhofer Group for Materials and Components – MATERIALS is covered by public-sector revenue, the Fraunhofer Group for Microelectronics has the highest share for industrial revenue, at 56 percent.

The Fraunhofer Group for Innovation Research – INNOVATION, which now has five member institutes, began operations in 2017 and achieved an operating budget of €70 million. The high share of its operating budget covered by public-sector revenue (54 percent) is an indicator of the group's socio-economic orientation, which includes advising policymakers and public-sector customers on matters related to research strategy and innovation processes.

Defense research

The defense research segment unites the R&D activities of the seven Fraunhofer Institutes that together form the Fraunhofer Group for Defense and Security VVS. The German Federal Ministry of Defence (BMVg) is the main provider of base and project-related funding for this segment. The objective of this research is to provide people, infrastructures and the environment with the best possible protection against potential security threats with a military or terrorist background. The defense-related institutes are also active in contract research, developing successful solutions for civilian applications in cooperation with industry and public-sector customers. In this way, the institutes support the concept of dual-use research and enable security issues to be studied from a holistic perspective.

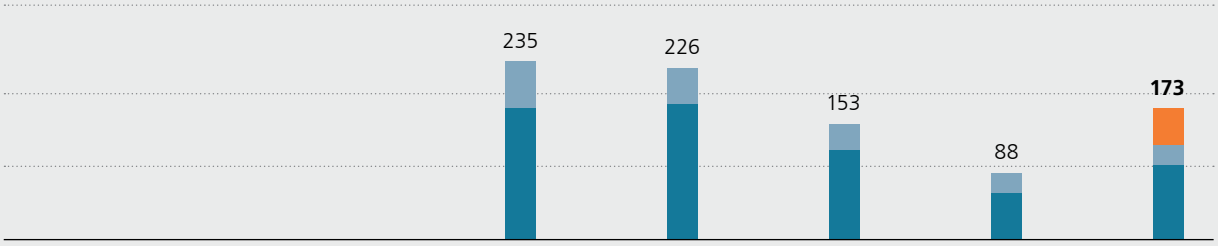
Budgeted expenditure for the defense research segment grew by 6 percent year over year to €121 million. Of that figure, €108 million was accounted for by the operating budget, which increased by 4 percent, and €13 million by capital expenditure, which rose by 30 percent. This budget growth was attributable entirely to BMVg project funding, which, after a decline the year before, returned to a high level of €57 million in 2017. At €64 million, the amount required from base funding was roughly the same as in the prior year.

Including its contract research activities, the Fraunhofer Group for Defense and Security VVS had an operating budget of €215 million, 17 percent of which was covered by industrial revenue and 51 percent by public-sector revenue.

Defense research: Budgeted expenditure and revenue, in € million

	2013	2014	2015	2016	**2017**
Budgeted expenditure	**114**	**118**	**127**	**114**	**121**
Operating budget	96	102	108	104	108
Capital expenditure budget	18	16	19	10	13
Revenue	**114**	**118**	**127**	**114**	**121**
Project funding (BMVg)	53	58	64	49	57
Additional funding requirement (BMVg)	61	60	63	65	64

Major infrastructure capital expenditure: Capital expenditure budget and revenue, in € million



	2013	2014	2015	2016	**2017**
Capital expenditure budget	**235**	**226**	**153**	**88**	**173**
Building projects (major and minor)	174	179	118	62	98
Equipping of new facilities	61	47	35	26	27
Research Fab Microelectronics Germany (FMD)					48
Revenue	**235**	**226**	**153**	**88**	**173**
Additional project funding (ERDF and other)	72	54	28	16	25
Additional project funding (BMBF for FMD)					48
Additional funding requirement (federal and state governments)	163	172	125	72	100

Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises all building projects and the associated equipping of new facilities with scientific instruments and furniture. As of 2017, this segment also included capital expenditure on scientific instruments for the Research Fab Microelectronics Germany (FMD), which is the product of several years of collaboration between 11 Fraunhofer Institutes and 2 Leibniz Institutes. Major infrastructure capital expenditure totaled €173 million in 2017.

At the launch of the FMD, Fraunhofer invested €48 million in scientific instruments, with project revenue for an equivalent amount coming from German Federal Ministry of Education and Research (BMBF) funds. Over the entire period of the project to set up the FMD, the BMBF will provide €350 million in funds, with Fraunhofer receiving €280 million and the two Leibniz Institutes €70 million. The FMD's goal is to strengthen microelectronics research in Germany, one of the country's key industries, and to upgrade its corresponding portfolio of laboratory equipment.

Compared with earlier years, capital expenditure on building projects and the equipping of new facilities was substantially higher in 2017. Capital expenditure on building projects rose by a total of €36 million to €98 million, €71 million (up €35 million) of which was for major and €27 million (up €1 million) for minor projects. At €27 million, capital expenditure on equipping new facilities was roughly on par with the previous year.

Special funding for major building projects (and their equipment) is provided by the federal government and the government of respective host state in a ratio of 50 : 50. The state governments often provide additional funding from the European Regional Development Fund (ERDF), which reduces the amount of funding required from federal and state governments alike. Minor building projects are financed from base funding in a ratio of 90 : 10. The funding required from the federal and state governments in 2017 totaled €100 million. ERDF funds from the states accounted for €21 million of project revenue, while €4 million was accounted for by other revenue.

Financial and net asset position

As of December 31, 2017, the Fraunhofer-Gesellschaft had total assets of €3186 million, up €235 million or 8 percent year over year. Assets presented in the ordinary accounts comprised 99.5 percent of total assets, with capital of the non-profit organization accounted for the remaining 0.5 percent.

Non-current assets accounted for 62 percent of assets and were €50 million higher at €1981 million. This increase was chiefly attributable to capital expenditure on property, plant and equipment exceeding depreciation of those assets. Property, plant and equipment grew by €34 million to €1933 million.

Current assets accounted for 38 percent of assets and were €187 million higher at €1193 million. This increase was mainly attributable to growth of €101 million in cash and cash equivalents (including bank account balances), which totaled €185 million on the reporting date. Of that figure, €83 million was base funding from the BMBF carried forward under the terms of the management statutes. In addition, the license-fee revenue reserve rose by €40 million, which increased the securities portfolio. Receivables from the federal and state governments in relation to project billing also rose by €40 million.

Equity – which comprises the non-profit organization's capital that is not financed by government grants (€15 million) and restricted reserves (€1 million) – decreased slightly. Economic equity also includes three kinds of special reserve

recognized in the balance sheet: The special reserve for grants relating to non-current assets increased in line with those assets, rising by €50 million to €1965 million. The special license-fee revenue reserve grew by €40 million to €339 million. The special reserve for the present value of deferred income from a patent deal came in at €73 million. This reserve is matched by other receivables of an equivalent amount on the assets side of the balance sheet.

The special reserve for grants used to finance current assets is used to account for income not yet received, less expenses not yet paid, by the reporting date. This essentially corresponded to advance project financing and amounted to €248 million as of the reporting date.

Provisions increased by €4 million to €157 million, €35 million of which was accounted for by provisions with maturities of more than one year. In the case of pension and compensated leave provisions, corresponding reimbursement claims totaling €66 million were entered on the assets side of the balance sheet.

Liabilities climbed by €138 million to €388 million. This increase was mainly due to a rise of €120 million (to €275 million) in unappropriated grants from the federal and state governments from base funding and project billing. There are no liabilities with maturities of more than one year.

As a beneficiary of public funds, the Fraunhofer-Gesellschaft is subject to budgetary constraints that prohibit it from making use of the capital markets or of lines of credit with banks. Nevertheless, the organization's **liquidity** is guaranteed at all times as it can regularly call on cash payments from its funding agencies under base funding arrangements. The funding mix for contract research corresponds to the proven Fraunhofer funding model and is on a solid footing.

Shareholdings and spin-offs

At the reporting date, the Fraunhofer-Gesellschaft held equity investments in a total of **85 companies** across a wide variety of sectors. The transfer of technology to industry formed the focus of activities at 61 of the companies in the investment portfolio, while the remaining 24 equity investments were of a strategic nature. There was considerable activity in Fraunhofer's investment portfolio in 2017. Overall, the organization spent €1.0 million to acquire equity interests. The Fraunhofer-Gesellschaft added 8 companies to its investment portfolio and divested its shares in seven. Valuation allowances reduced the total carrying amount of equity investments (including shares in associated companies) to €8.8 million (2016: €9.8 million). Income from the divestiture of equity investments came to €1.1 million.

Spin-offs are an integral component of the Fraunhofer-Gesellschaft's strategy for exploiting its industrial property rights. The Fraunhofer Venture department typically provides support to the founders during the preparation phase of the spin-off. In individual cases, Fraunhofer takes a minority share in the spin-off company as part of the technology transfer process. In 2017, Fraunhofer Venture provided support to 33 new spin-off projects, and 25 new businesses were spun off from the Fraunhofer-Gesellschaft. Fraunhofer's goal is to increase both the number of spin-offs and the share of industrial revenues they account for, and has put in place a variety of measures and programs to achieve this.

Fraunhofer's only fully owned subsidiary in Germany is **PIA gGmbH** in Kaiserslautern. Since 2015, PIA has been acting as an independent office under contract to the German Federal Ministry of Finance and is responsible for carrying our risk-benefit analyses of pension insurance products. In 2017, its provisional revenue amounted to €0.7 million.

Fraunhofer manages and operates its R&D activities outside Germany through eight legally independent **international subsidiaries** (comprising five commercially registered subsidiaries, two foundations and one association). In turn, these entities have their own business divisions and research centers, which cooperate closely with the Fraunhofer Institutes in Germany. The Fraunhofer-Gesellschaft's international subsidiaries will be further discussed in the "International activities" section below.

International activities

In the competitive international research marketplace, Fraunhofer is a highly sought-after partner for industrial enterprises and scientific organizations alike. Fraunhofer's internationalization strategy is based on the principle of creating scientific value for Fraunhofer and generating positive effects both for Germany, Europe and the partner country in question. Working in collaboration with the world's best in every field enables Fraunhofer to develop future-proof solutions and innovative responses to global challenges.

Fraunhofer has developed a variety of formats for partnering leading international centers of excellence. The Fraunhofer-Gesellschaft's eight independent **international subsidiaries** are the most institutionalized form of international partnership:

- Fraunhofer USA, Inc.
- Fraunhofer Austria Research GmbH
- Fraunhofer Italia Research Konsortial-GmbH
- Fraunhofer UK Research Ltd
- Fundación Fraunhofer Chile Research
- Associação Fraunhofer Portugal Research
- Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik (in Sweden)
- Fraunhofer Singapore Research Ltd. (since 2017)

The subsidiaries function as the legal entities for the – currently 16 – **Fraunhofer Centers** outside Germany. The latter are institutionalized Fraunhofer partnerships with local universities, enabling long-term research activities abroad. Establishing a local legal entity is a prerequisite for participation in national public-sector funding programs and for receiving base funding from the partner country concerned. As their work is not profit-oriented, the subsidiaries generally qualify for base funding from the partner countries, and they are financed in line with the Fraunhofer funding model.

Fraunhofer Singapore Research Ltd., Fraunhofer's first subsidiary in Asia, was established in April 2017. It has its roots in the Fraunhofer Project Center for Interactive Digital Media, which was set up in 2010. Under the patronage of Nanyang Technological University until 2017, the center will now be run by Fraunhofer Singapore. The Fraunhofer-Gesellschaft is the sole owner of this non-profit organization. On the basis of preliminary data, Fraunhofer Singapore's operating budget was equivalent to €1.5 million for the short financial year from April 1 to December 31, 2017, and its project revenue from contracts with third parties amounted to around €0.2 million.

The Fraunhofer Project Centers (FPCs) are vehicles enabling Fraunhofer Institutes to collaborate with international research organizations on particular topics for limited periods of time. In each case, the partner organization sets up the FPC as a local legal entity and cooperates closely with a Fraunhofer Institute in Germany on the chosen topic. The aim of this form of collaboration is to carry out joint contract research projects for customers and take part in projects funded by the public sector. Three new FPCs were established in 2017:

At the University of Twente in the Netherlands, the Fraunhofer Project Center for Design and Production Engineering for Complex High-Tech Systems **FPC@UT** is developing new technologies for smart products in the fields of energy, transportation, medicine and security.

At Dublin City University, the Fraunhofer Project Centre for Embedded Bioanalytical Systems **FPC@DCU** is conducting research into microfluidic lab-on-a-chip systems for medical, pharmaceutical, manufacturing and analytical applications.

In partnership with the Technological Institute of Aeronautics in Brazil, the Fraunhofer Project Center for Innovations in Advanced Manufacturing **FPC@ITA** is developing and optimizing innovative manufacturing technologies, machinery and control systems, e.g. for the production and assembly of structural subsystems for aircraft.

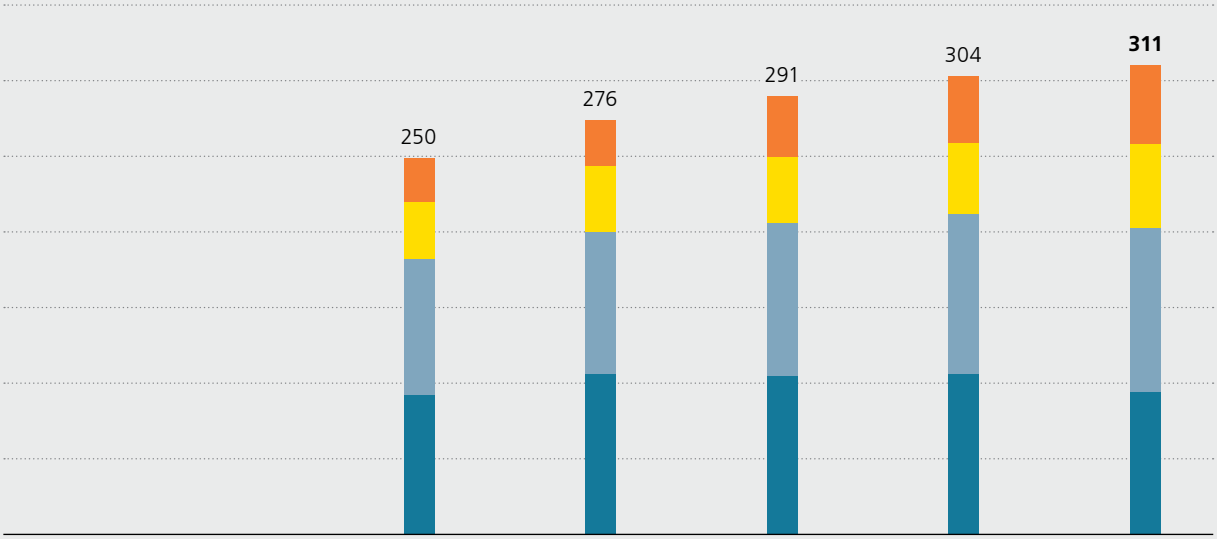
Fraunhofer's internal program **ICON** (International Cooperation and Networking) is another way of enabling strategic project-based partnerships with international universities and non-university research organizations of excellence. In 2017, the ICON program was instrumental in initiating two new partnerships with leading centers of excellence:

The International Consortium for Anti-Infective Research (**iCAIR**) – a joint project of Fraunhofer ITEM, the Institute for Glycomics of Griffith University, Gold Coast, Australia, and Hannover Medical School (MHH) – is focusing on developing new treatments for multiresistant pathogens.

In the **TRANSNEURO** project (Transatlantic network for neurovascular diagnostics and therapeutics), Fraunhofer EMB is working together with Massachusetts General Hospital to find new ways of treating acute and chronic cerebrovascular diseases.

High levels of **international revenue** reflect Fraunhofer's success in the global research market. In 2017, international revenue (excluding license-fee revenue) totaled €311 million, up by a slight 2 percent year over year. The Fraunhofer Institutes in Germany accounted for €279 million of that total, while the remaining €32 million was generated by the international subsidiaries through contracts with third parties. Some 30 percent of international revenue came from EU funds, 35 percent from customers and partners in Europe, and 35 percent from those outside Europe.

Revenue from work with international customers and partners, in € million



	2013	2014	2015	2016	**2017**
International revenue[1]	**250**	**276**	**291**	**304**	**311**
Additional project funding (EU)	92	106	105	106	94
Europe	90	94	101	106	109
North and South America	38	44	44	47	55
Asia	29	30	40	44	52
Other countries	1	2	1	1	1

1 Includes international subsidiaries' project revenue generated with third parties (2017: €32 million, 2016: €29 million); excludes license-fee revenue.

The **EU Commission** is a key source of public-sector funding for Fraunhofer and, through its participation in the Horizon 2020 framework programme, the Fraunhofer-Gesellschaft is helping actively to shape Europe's economic and research environment. In terms of funding received, Fraunhofer ranks third among the top 15 participating institutions. Nonetheless, EU revenue declined in 2017, by 11 percent year over year to €94 million. The reason for this decrease was that, for the first time, the funds stemmed mainly from the Horizon 2020 framework programme launched in 2014, the initial annual budget for which was substantially lower than that of the previous framework programme.

Revenue generated with customers and partners in **Europe** came to €109 million in 2017. Switzerland was the largest European market, with total revenues of €21 million, followed by Austria (€19 million) and the UK (€10 million). Fraunhofer's five European subsidiaries made a decisive contribution to its financial success, generating provisional project revenues from contracts with third parties: €4.1 million in Sweden, €3.2 million in Austria, €1.7 million in Portugal, €2.0 million in the UK, and €0.6 million in Italy.

In **North and South America**, Fraunhofer generated revenue of €55 million, up 17 percent year over year. The United States alone accounted for €48 million of that, with Fraunhofer USA generating €18 million. The next-ranking location was Chile, Fraunhofer's largest market in South America, with €2.5 million. Fraunhofer Chile accounted for €2.1 million of that figure.

In **Asia**, Fraunhofer achieved revenue growth of 18 percent in 2017, posting total revenue of €52 million. With revenues of €16 million each, China and Japan were again well ahead of the other Asian markets. Fraunhofer generated €1.5 million in revenue in Singapore, €0.2 million of which with its newly founded subsidiary Fraunhofer Singapore.

Intellectual property activities

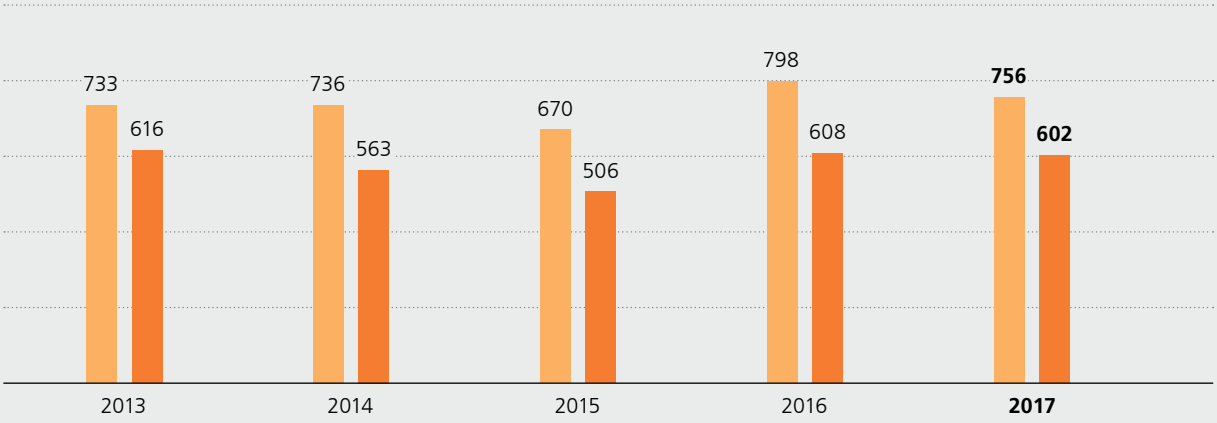
Fraunhofer remains the leader among German research institutions in terms of annual number of invention disclosures, patent applications, and total industrial property rights. Its performance is outstanding even when compared with that of industrial enterprises. Over the last ten years, Fraunhofer has always ranked among the German Patent and Trade Mark Office's 10 to 20 most prolific patent applicants, and has consistently held positions ranging between 5th and 10th in the number of trade marks registered. Similar statistics compiled by the European Patent Office (EPO) have placed Fraunhofer among the most active patent applicants for many years.

As a result of this performance, Fraunhofer ranked among the **Top 100 Global Innovators** in 2017 – for the fifth successive year. Clarivate Analytics (previously Thomson Reuters media group) presents this award to companies and organizations on the basis of the number and quality of patented inventions. Apart from Fraunhofer, four German industrial companies featured in the Top 100 in 2017.

In 2017, employees of the Fraunhofer-Gesellschaft submitted 756 invention disclosure reports. Of these, 602 were filed with the relevant patent offices as patent applications claiming rights of priority, which corresponds to a rate of more than two patents filed per working day. Fraunhofer's portfolio of active patent families, each of which comprises all active rights in different countries, rose to 7011. The total number of patents granted to Fraunhofer in Germany was 3367.

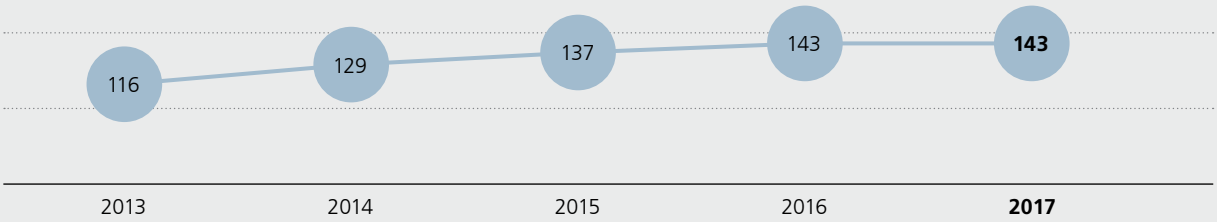
To guarantee a continuous flow of revenue from the exploitation of intellectual property rights, patents owned by different institutes are increasingly being grouped together in application-specific portfolios to create offers for selected companies. This approach creates new opportunities to generate income from licensing agreements and R&D projects. In 2017, targeted IP

Number of invention disclosures and patent applications claiming rights of priority



Invention disclosures
Patent applications claiming rights of priority

License-fee revenue, in € million



portfolios were put together for thematic areas such as glass, bionics, smart home and e-health, each comprising relevant patent families stemming from the work of multiple institutes.

The Fraunhofer-Gesellschaft generates revenue from the commercialization of industrial property rights not only with license fees, but also by utilizing patent pools. The most successful pools of this kind contain patents for audio and video encoding. The pools – which include not only standard-relevant Fraunhofer patents, but also those owned by parties in various other countries – are a vehicle for granting licenses worldwide, enabling Fraunhofer to commercialize patents in well over 100 countries. The income from these pools is reinvested in pre-competitive research and makes a lasting contribution to strengthening Germany's position as a research hub.

In 2017, Fraunhofer concluded 390 new licensing agreements. Although the total number of active licensing contracts declined marginally year over year to 2692, license-fee revenue was again high at €143 million.

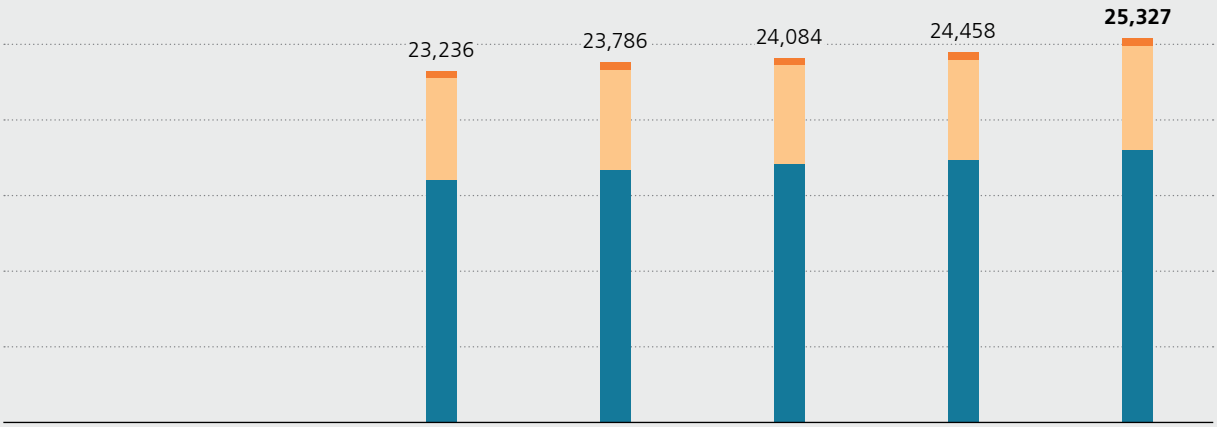
Employees

At year-end 2017, Fraunhofer had 25,327 employees, 17,965 of whom were research, technical or administrative staff (RTA staff), 6888 graduate, undergraduate or school students, and 474 trainees. That corresponded to a year-over-year increase of 3.6 percent or 869 employees in 2017. Personnel growth was thus much stronger in 2017 than in the prior year, where the corresponding figure was a rather subdued 1.6 percent.

In accordance with its mission statement, the Fraunhofer-Gesellschaft offers its employees the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility either at Fraunhofer or in other areas of science or industry. This approach, which builds on the Fraunhofer Guiding Principles, makes clear that, for the overwhelming majority of employees – especially research personnel – Fraunhofer represents an important stage in their individual careers. Fraunhofer offers both careers in management as well as career paths as specialists. The latter have already been formalized at a number of Fraunhofer Institutes. Careers may continue outside the Fraunhofer environment (springboard careers) in line with the organization's mission of **knowledge transfer**. Experience gained at Fraunhofer prepares employees not only for a later career in industry or science, but also for starting up spin-offs.

Against this backdrop of knowledge transfer, Fraunhofer's high employee turnover rates among RTA staff are a positive phenomenon. In 2017, 1509 RTA staff left the organization, while 2142 employees were newly hired. Three-quarters of new recruits were young researchers embarking on a career. Overall, at year-end, Fraunhofer employed around 9800 scientists, accounting for 55 percent of all RTA staff.

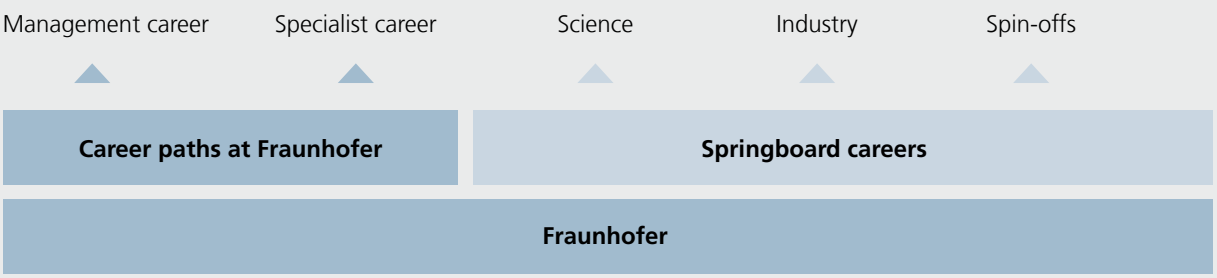
Employees (number at year-end)



	2013	2014	2015	2016	**2017**
Employees	**23,236**	**23,786**	**24,084**	**24,458**	**25,327**
RTA staff (total)	16,048	16,687	17,078	17,332	17,965
of which: research [1]	8841	9125	9295	9371	9792
of which: technical and administrative	7207	7562	7783	7961	8173
Graduate, undergraduate and school students	6694	6619	6554	6654	6888
Trainees	494	480	452	472	474

1 Employees in pay group 13 and higher, area of responsibility: "scientific research."

Career paths at Fraunhofer and springboard careers beginning at Fraunhofer

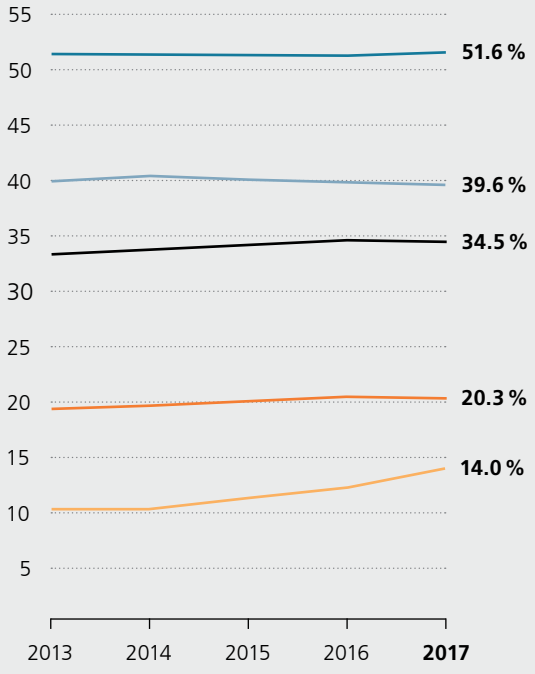


The **guidelines on short-term contracts** launched in 2013 are being systematically implemented at the Fraunhofer Institutes. In recent years, targeted discussion of the topic and sustained monitoring helped reduce the share of research employees on short-term contracts by 3.5 percentage points to 59.7 percent at year-end 2017. The ratio of technical and administrative employees on short-term contracts was 29.7 percent. Overall, 46.1 percent of RTA staff are employed on short-term contracts.

Around 10 percent of Fraunhofer's employees are from outside Germany. A key factor in positioning Fraunhofer as an attractive employer in the international employment market, particularly in the science and research segment, was its signing of, and compliance with, the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers (EU Charter & Code, for short). The EU considers the 40 principles contained in the EU Charter & Code to be critical criteria in ensuring that scientific organizations remain attractive and economically successful. This formed the basis of the Human Resources Strategy for Researchers – HRS4R submitted by Fraunhofer to the EU Commission in 2016 as part of its application to use the EU's **HR Excellence in Research** logo. In December 2017, the EU Commission officially bestowed this logo on the Fraunhofer-Gesellschaft, making it the second applied research organization in Germany to be thus honored.

Vocational training is an integral part of Fraunhofer's personnel development strategy. Fraunhofer offers a wide and diverse range of vocational training courses and possible careers, providing training for 40 or so different professions in six career groups. Of the organization's 474 trainees, 431 are in dual vocational training courses and 43 in dual study programs that combine practical training and theory to differing degrees.

Share of RTA staff who are women, in %



1 Excluding heads of institutes and directors.

Diversity

Diversity is an issue that concerns all HR functions at Fraunhofer. Equal career opportunities for women and men, and the inclusion of people with disabilities, are the action areas that have been accorded top priority. Other aspects of diversity include an international mix of employees and achieving a healthy work-life balance.

Providing women and men with equal career opportunities is a key component of the organizational culture at Fraunhofer. An important goal in this endeavor is to win over more women for applied research and to develop their careers. At the end of 2017, **women** accounted for 20.3 percent of all **research staff**, meaning we only just fell short of our self-imposed goal of 21.0 percent. In 2017, the recruitment ratio for female scientists was 24.8 percent, which was actually higher than the measurable ratio for female applicants as a whole (23.0 percent). In order to achieve any substantial increase in the percentage of female researchers at the organization, however, Fraunhofer will have to make an even stronger commitment to the recruitment of young female talent. By contrast, the proportion of women in technical and administrative posts is comparatively high (51.6 percent). Viewed across the whole range of RTA staff, the average share of women in the Fraunhofer workforce is 34.5 percent.

The **share of women in scientific management positions** exhibited a positive trend. Across all levels of management, the share of women grew from 11.1 percent in 2015 to 13.5 percent at year-end 2017. At 14 percent, the share of women in management level 2 positions (excluding heads of institutes and directors) was even substantially higher than our goal of 13.3 percent. It was the third year in a row that Fraunhofer achieved its goal at this management level. The TALENTA career and development program for female scientists was a decisive factor in this positive trend, as was borne out by an assessment conducted in 2017 with the support of external experts. At the end of 2017, around 39.6 percent of managers in technical and administrative positions were women. Thus, viewed across the whole range of RTA staff, some 19 percent of managers are women.

A new focus of activity initiated in 2017 is to support more women of excellence in attaining professorships (W2/W3 level). The main goal of this initiative is to help more female scientists into senior management positions. As part of a project on gender-neutral paths to career excellence, Fraunhofer has been supporting selected female scientists in their quest to qualify for future professorships at universities and institutes of technology. The Fraunhofer Institutes at which the women concerned are employed develop personalized career development plans with them and, at a strategic level, help coordinate partnerships with the potential universities.

Beyond that, Fraunhofer is aspiring to increase the representation of women on scientific and supervisory boards. In particular, the plan is to achieve a share of 30 percent on the institutes' advisory boards by 2020. At year-end 2017, the corresponding figure was 13.4 percent – with the mandates of those sitting on more than one advisory board being counted individually. Women accounted for 31 percent of all new advisory board members appointed in 2017. In the Fraunhofer Senate, the organization's highest steering committee, women accounted for 29 percent of the positions elected by the General Assembly.

As a beneficiary of public funds, Fraunhofer must act as a role model when it comes to promoting and securing equal participation for men and women, especially in the work setting. As for the **inclusion of those with severe disabilities**, Fraunhofer has set itself the target of increasing the proportion of such people in its workforce to 3.4 percent by 2020. At year-end 2017, the ratio was 2.7 percent. Broken down by type of work, the figures were 1.7 percent for research staff, 6.0 percent for technical staff and 5.1 percent for administrative staff.

The long-term goal is to systematically raise the percentage of people with disabilities among research staff. A central program for this was launched at the end of 2017 and is still in the ramp-up phase. Two applications for funding submitted by the institutes have already been approved for a total volume of around €40,000. The funds are intended to help with the recruitment of people with disabilities and/or to provide them with the necessary infrastructure.

Social commitment

Many Fraunhofer employees play an active role in various campaigns at their institutes to collect donations for children and adolescents, a case in point being the Offene Jugendwerkstatt Karlsruhe e. V. project organized by Fraunhofer ICT.

Above and beyond such campaigns, Fraunhofer recognizes that, to the extent possible for a research organization, it has a responsibility to help with the integration of refugees. A key factor in the integration of refugees is easing their way into the employment market. Often, however, the direct route to employment poses difficulties for the refugees themselves and for the potential employers. That is why Fraunhofer has developed a plan to integrate refugees via three different channels: internships, training positions and RTA staff positions. This will help enhance the refugees' future prospects in the employment market.

The plan will be tailored to the specific requirements of each state in cooperation with the respective Fraunhofer Institutes and will be financed by state government funds. The refugees are looked after at the institutes by sponsors in accordance with their particular needs. Implementation of the plan began in Saxony in 2016, with Baden-Württemberg and Bavaria following in 2017. Thus far, a total of 57 orientation internships have been assigned to refugees in these three states as well as 5 training positions and 16 short-term RTA positions. There are already signs that the Fraunhofer programs are enhancing refugees' chances of finding follow-on employment.

Governance

Governance is another area of corporate responsibility at Fraunhofer. It involves the integration of the principles of responsibility into the organization's strategy, guidelines, rules and culture. Since 2014, the Fraunhofer-Gesellschaft has published sustainability reports, detailing its goals, measures in place and latest figures for each area of corporate responsibility. In this context, Fraunhofer published a statement in 2017 concerning its compliance with the **German Sustainability Code** (GSC) reporting standard. What is more, Fraunhofer became a signatory to the UN Global Compact, voluntarily undertaking to report at least once every two years on its progress with regard to the Compact's ten universal sustainability principles. The next progress report on corporate responsibility and sustainability is due to be published in fall 2018.

In order to entrench the idea of corporate responsibility more firmly in Fraunhofer's existing structures, the Executive Board decided in October 2017 to set up a **Corporate Responsibility Board** at the level of the Presidential Council, whose members will be drawn from different Executive Board functions and from different institutes. The aim is to create as streamlined a decision-making structure as possible for the strategic management of this overarching topic, making it possible to address key corporate responsibility issues in unison.

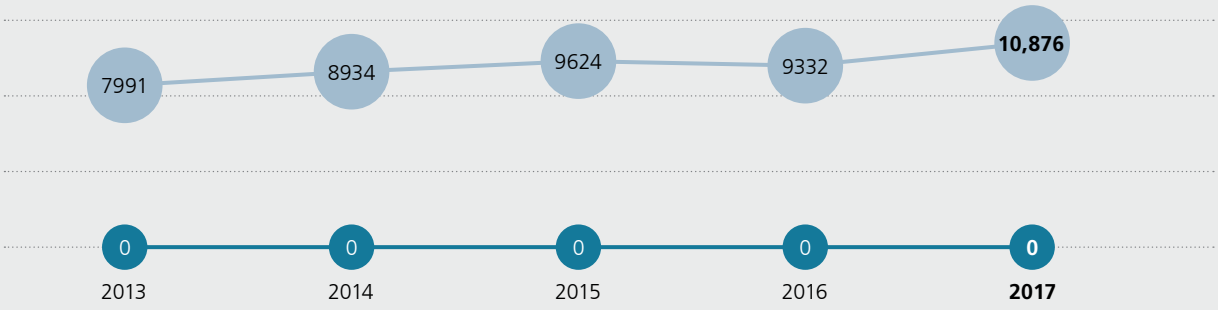
Resources and procurement

In line with the German Energy Services Act (EDL-G), Fraunhofer conducted its first energy audit in accordance with DIN 16247-1 in 2015. Such audits are to be carried out every four years. The individual institutes are responsible for implementing, on an ongoing basis, the energy-saving measures recommended in the audit. The experience gained from the first audit was taken as a basis in 2017 to formulate uniform standards for conducting the next one, due in 2019.

Fraunhofer collects data annually on the CO_2 emissions it generates through business trips by train and plane. In recent years, the number of business trips across Fraunhofer as a whole has risen continuously due to the rising number of employees and to the growing volume of research carried out. Thanks to the framework agreement between the federal government and German Rail (Deutsche Bahn), all rail travel is carbon-neutral – an option that is not yet available for air travel. Fraunhofer's CO_2 emissions from air travel amounted to around 10,876 metric tons in 2017, or roughly 0.6 metric tons of CO_2 per full-time equivalent.

The Fraunhofer Institutes have appointed dedicated officers to handle waste management at the individual locations and to document their activities in a waste register and corresponding annual report. In 2017, the institutes generated 5681 metric tons of non-hazardous waste and 620 metric tons of hazardous waste. Most hazardous waste relates to specific projects and thus varies from year to year. What is more, some waste is generated only very seldom. It is often stored for years so that it can be disposed of in large quantities, thus reducing transportation costs. As regards the procurement of products and services, all tenders for new master agreements and projects placed since 2016 have, wherever feasible, been tied to product- and service-specific social and ecological criteria. Against this backdrop, the Fraunhofer Institutes purchased around 18 percent of their electricity from renewable sources in 2017.

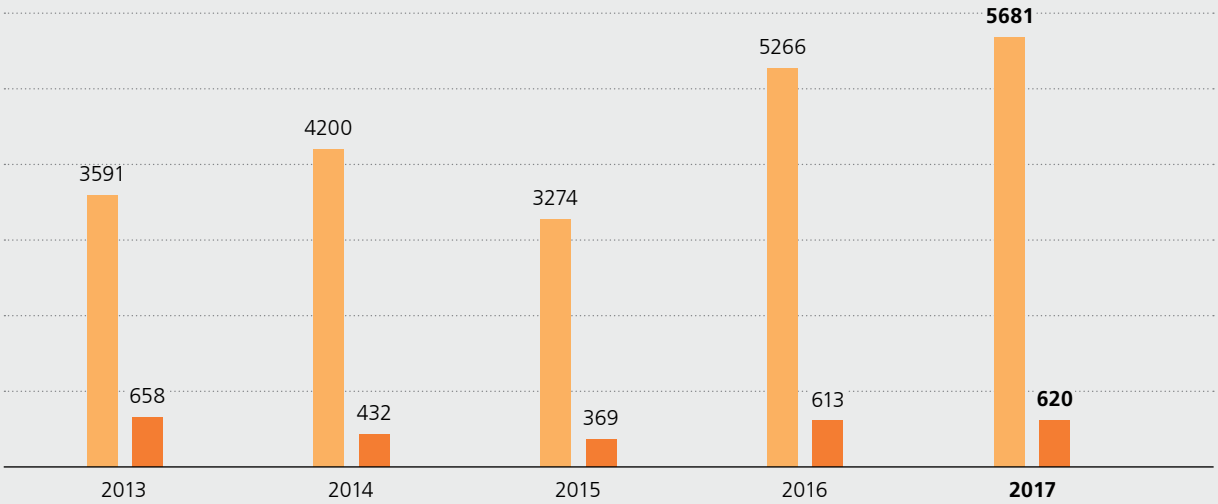
CO_2 emissions from business travel by Fraunhofer employees, in metric tons



Air travel

Rail travel: carbon-neutral due to Fraunhofer's participation in the bahn.business program

Volume of waste produced by Fraunhofer Institutes, in metric tons[1]



Non-hazardous waste

Hazardous waste

1 Volume of waste calculated partly on the basis of estimates by the Fraunhofer Institutes.
In cases where no information had been received before this report went into print, the calculation is based on prior-year figures.

Research and development

Many of Fraunhofer's research solutions contribute to the goals of sustainable growth and to tackling the challenges faced by society, e.g. with respect to climate change, health and environmental protection. This contribution to society is promoted by means of appropriate structures and activities.

As part of the Fraunhofer 2022 Agenda, seven Key Strategic Initiatives were defined in 2017, representing areas in which Fraunhofer would like to attain a leading position going forward. One of these is **biological transformation**, i.e. the convergence of nature and technology with the goal of achieving sustainable value creation. Through the use of biological resources, and the integration of the processes and principles of living nature into technical innovations, this new focal topic has the potential to make a decisive contribution to creating more-sustainable economic processes and thus solving ecological and social problems.

Founded in 2015, the **High-Performance Center Sustainability** is a partnership between the five Freiburg-based Fraunhofer Institutes and the University of Freiburg. In early 2018 the center received a positive evaluation from an independent expert. The goal of the center's research is to find solutions to the problem of resilience in complex infrastructure systems and to questions raised by the transition to a renewable energy regime, such as energy storage and energy system technologies as well as battery safety and building services. The Fraunhofer Institutes and the University of Freiburg are collaborating in the high-performance center on an equal footing in order to develop innovative, sustainable products and services for, and in partnership with, SMEs. The High-Performance Center Sustainability is one of 17 such regional centers, which are to evolve into a future-oriented network for research transfer in Germany with a clear international profile.

The **F4D – Fraunhofer for Development** program was established in 2016 and the pilot phase ended in 2017. The purpose of this new business endeavor is to bring Fraunhofer expertise to bear in the international development arena. Under the program, ten projects involving Fraunhofer were launched in emerging and developing countries such as Uganda, Kenya and Colombia. Following an evaluation of the pilot phase, an Open Innovation Platform was organized at the start of 2018 in cooperation with World Association of Industrial and Technological Research Organizations (WAITRO).

Social responsibility in R&D also means ensuring that the research processes themselves are responsible. Activities to safeguard scientific integrity are ongoing and, in 2016, measures were introduced to inform and advise Fraunhofer scientists on how to handle ethical questions raised during their research. These activities and measures provide the basis for the deeper integration of aspects such as ethics, open access and social participation at Fraunhofer, and are the focus of the EU-sponsored **JERRI** project (Joining Efforts for Responsible Research and Innovation) that was launched in 2016 under the leadership of Fraunhofer ISI.

RISK SITUATION AND OUTLOOK

Risk management and risks

The **risk management** system is designed to identify existing and potential risks at an early stage and to manage them by means of appropriate measures in such way that they either do not materialize at all or do not have consequences that could endanger Fraunhofer's business success or jeopardize its ability to fulfill its mission in accordance with its statutes. Fraunhofer understands risk to mean all internal and external events and developments that might threaten the organization's success. These include both risks that can be given a monetary value and those of a qualitative nature.

The central departments inform the Executive Board of relevant risk-related developments – both routinely and on an ad hoc basis – via the established reporting channels. Once a year, Fraunhofer asks its **risk assessment experts** to carry out a systematic review of the risk situation. The results are summarized and prioritized in a separate risk report. For the purposes of risk reporting in the context of this annual survey, individual risks are classified according to the four categories of most interest to Fraunhofer, namely business model, financing, resources, and business operations. The risk management structures and processes are set down in the Fraunhofer-Gesellschaft's risk management manual.

Business model risk encompasses those types of risk that represent a threat to the continuation and evolution of the Fraunhofer funding model. Such risks may arise from external sources or from internal differences in the way the Fraunhofer model is applied.

As a not-for-profit organization and beneficiary of public funds, Fraunhofer keeps a close eye on changes in legislation and taxation that might affect its access to financial support and continuously evaluates these changes with respect to their possible impact on the financing of its activities.

Fraunhofer maintains an ongoing dialog with the funding agencies at federal, state and EU level and, if necessary, makes appropriate amendments to its funding model so that it continues to comply with current funding legislation.

Established strategy planning processes permit constant feedback from relevant market players in Germany, Europe and worldwide as well as assuring ongoing enhancement of Fraunhofer's diversified research portfolio. By determining and analyzing research indicators, the individual institutes and groups support Fraunhofer in safeguarding its scientific excellence in the long term.

Fraunhofer contributes the results of its research – such as patents and intellectual property rights – into existing companies or its own start-ups. This may involve subsequently disposing of the equity investments or generating income for Fraunhofer through research contracts. The development of equity investments is constantly monitored by the financial controlling department.

Financial risks may arise for the Fraunhofer-Gesellschaft from contingent liabilities and operational risks in connection with its international subsidiaries. The American subsidiary Fraunhofer USA, Inc. is currently engaged in legal action with a company in the United States for the alleged infringement of intellectual property rights. The lawsuit is being handled by Fraunhofer USA with the support of the Fraunhofer-Gesellschaft.

The controlling system for Fraunhofer's international activities is updated whenever necessary to take account of changes in the national and international operating environment. The financial controlling department constantly monitors the performance and liquidity of Fraunhofer entities outside Germany.

A key issue in the context of **financial risks** is that of containing risks that might compromise Fraunhofer's access to research funding or the organization's solvency.

Base funding from the federal and state governments is one of the three main pillars of the Fraunhofer funding model. In particular, such funding enables Fraunhofer to establish new fields of research using a quality-assured process. In order to maintain the share of base funding in the funding mix in the long term, Fraunhofer proactively manages its growth and lobbies the funding agencies to maintain its base funding at a level in keeping with its mission and in proportion to its performance.

In the area of public-sector projects, funding issues and instruments are constantly evolving at the federal, state and EU levels. Altered funding conditions, such as the introduction of flat rates, harbor the risk that income from projects may be lower than calculated under the full-cost method on which the Fraunhofer funding model is based. That is why Fraunhofer negotiates with the relevant EU and national bodies to gain approval for its costing models and ensures, through regular audits and continuous improvements, that its system of cost reimbursement meets all the relevant requirements.

Fraunhofer counters the risk of a possible decline in its project revenue from industrial research contracts by developing new areas of research and collaboration models geared to market requirements, and by strategically expanding its customer acquisition and loyalty activities, especially at a cross-institute level.

Systematic checks by the central controlling department are used to keep track of the spending and earnings of individual institutes. Regular comparisons of each institute's results with respect to its annual targets permit the identification of downward trends, enabling the necessary countermeasures to be elaborated and implemented in good time.

Projects for building and equipping new facilities that are co-financed by the federal and state governments and the EU (ERDF) are subject to restrictions concerning how long the funds are made available. If projects encounter lengthy delays, that may result in the late payment, or even forfeiture, of the funds. Fraunhofer has a construction controlling unit in place to closely monitor the progress of projects to build and equip new facilities and constantly looks for ways to expedite such projects.

Continual monitoring of prefinancing and accounts receivable, coupled with effective dunning and contractually agreed payment terms, help to minimize credit risk, which essentially relates to project prefinancing and unrecoverable payments.

Resource risk encompasses those types of risk that may affect the availability of material and intangible resources needed to successfully carry out research activities.

The Fraunhofer-Gesellschaft preserves and expands its research expertise by recruiting highly qualified scientists and encouraging them to stay with Fraunhofer. To ward off the potential risk of being unable to recruit a sufficient number of qualified specialists, Fraunhofer maintains close ties with universities, which are one of its main sources of new employees, and pursues a sustainable HR policy that respects diversity and is geared to long-term staffing requirements.

Protecting and developing the organization's intellectual property (IP) base is a critical factor in Fraunhofer's success and a prerequisite for the exploitation of research results. Fraunhofer constantly monitors initiatives stemming from the regulatory environment and assesses them for possible negative impact on the conditions governing the protection and exploitation of intellectual property rights.

Fraunhofer is exposed to capital market risk insofar as it invests part of its capital and reserves with a view to earning a return. The investments are concentrated in open-end funds within the meaning of the German Investment Act and in closed-end funds. The organization pursues a widely diversified investment policy and, in view of the uncertainty prevailing in the money and capital markets, keeps a constant watch on the risk situation.

Fraunhofer has financial reserves at its disposal, ensuring that, in the long term, it can fulfill its mission as defined in its statutes. An important instrument in this regard is the option provided for in its management statutes to carry forward base funding from one financial year to the next. If this option were curtailed, it would limit Fraunhofer's liquidity and its ability to make provision for risks and restrict its freedom of action.

Operational business risk comprises those types of risk that may arise from processes used in research and administration, or from the execution of specific research projects.

Through its contract research projects with German and international business partners, Fraunhofer is exposed to liability and performance risks such as product liability and warranty. It manages these through suitable liability restriction clauses in its standard terms and conditions of business and in its standard contracts, as well as through a multi-tier approval process based on competent legal advice.

With requirements rising all the time, Fraunhofer is constantly optimizing its rules and procedures to ensure that its business processes are designed and implemented in compliance with laws and regulations. A compliance management system is in place to ensure that the subject of rules, and compliance with them, is dealt with in a systematic manner. The internal audit department monitors compliance with internal rules and control mechanisms at regular intervals or on an ad hoc basis.

The application of strict IT security measures is of elementary importance to the ongoing existence of a knowledge-based research organization. Fraunhofer takes targeted measures to mitigate potential IT risks. These measures are defined in a binding IT security manual.

The current **overall assessment** of the Fraunhofer-Gesellschaft's risk situation reveals nothing that could endanger its existence in the long term.

Outlook

On the basis of its current planning for 2018, Fraunhofer expects to post a substantial increase in business volume, which will rise by 14 percent to €2.6 billion. Higher capital expenditure will be the main driver of this strong growth. For one thing, capital expenditure on building projects will rise; for another, the Research Fab Microelectronics Germany will continue to grow. Fraunhofer expects to see solid growth in contract research, with budgeted expenditure rising by 5 percent to around €2.1 billion. This will reflect not only growth in project revenue, but also rising funding requirements from higher base funding.

Fraunhofer deploys quality-assured tools and processes to organize and deliver quantitative growth. These include transparent, integrated planning of the R&D portfolio at several levels of the organization, new instruments to promote internal networking and enhance excellence, and an array of personnel measures designed to encourage the careers of employees, especially those of women.

With its 2022 Agenda, Fraunhofer is aligning itself with its mission on the basis of the recently revamped Fraunhofer Guiding Principles. Its goal is to implement the vision they embody by becoming the trendsetter and technology leader in Germany in certain areas of R&D, e.g. in digitalization and biological transformation. Fraunhofer is systematically adapting its processes and management to achieve this goal. The Executive Board and Presidential Council are monitoring the progress and quality of a total of ten operational projects to implement the Fraunhofer 2022 Agenda.

Fraunhofer is also pursuing the voluntary commitments it entered into with the Joint Science Conference (GWK) under the Joint Initiative for Research and Innovation III. In some areas, Fraunhofer has already achieved the targets set for 2020. For instance, prioritized research topics are being coordinated among the different institutes and internal funding programs that are geared to fostering competition and that utilize 10 percent of base funding are being carried out. Similarly, a program to raise the share of women scientists at all career levels has been put in place.

In both strategic and structural terms, Fraunhofer is exceptionally well placed to tackle today's technological and social challenges and, going forward, will continue to position itself as an innovation partner and provider of impulses for industry, the public sector and society.

The Executive Board would like to thank the organization's members, patrons, friends and, most of all, the staff of the Fraunhofer-Gesellschaft for their support, dedication and hard work last year.

Fraunhofer-Gesellschaft
zur Förderung der angewandten Forschung e. V.

The Executive Board
Prof. Dr.-Ing. Reimund Neugebauer
Prof. Dr. rer. publ. ass. iur. Alexander Kurz
Dipl.-Kfm. Andreas Meuer
Prof. Dr. rer. nat. Georg Rosenfeld

REPORT OF THE SENATE ON THE FINANCIAL YEAR 2017

In 2017, the Fraunhofer-Gesellschaft expanded its position qualitatively and quantitatively as a key player in applied research in Europe. As a consequence of adjusted institutional funding, Fraunhofer was able to successfully continue its mission, particularly with the aid of the targeted expansion of cross-institute pre-competitive research. Instruments include new research infrastructures such as internal Clusters of Excellence and the Research Fab Microelectronics Germany (FMD) investment program funded by the German Federal Ministry of Education and Research, which is being implemented by Fraunhofer together with the Leibniz Association on a cross-organizational basis. In addition, Fraunhofer has founded a platform for technology-related questions of the future with the new Fraunhofer Group for Innovation Research.

The Fraunhofer-Gesellschaft's solid financial statements for 2017 again received an unqualified audit certificate from the independent auditors.

In 2017, the Senate fulfilled the duties with which it is entrusted under the Statute of the Fraunhofer-Gesellschaft. It convened twice in the course of the financial year: on May 30 at the International Congress Center in Dresden and on October 18 at the Kempinski Hotel in Frankfurt am Main.

The main decisions taken in accordance with the Statute concerned the Fraunhofer-Gesellschaft's structure and the composition of the Executive Board:

– By resolution of the Senate, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES was split into two separate institutes as of January 1, 2018: the Fraunhofer Institute for Wind Energy Systems IWES based in Bremerhaven and the Fraunhofer Institute for Energy Economics and Energy System Technology IEE based in Kassel. Since their parent institute was incorporated into the Fraunhofer-Gesellschaft nine years ago, both branches of the institute had developed extremely well in terms of size, funding and profile on the research market and were already operating completely independently of each other in practical terms.

– LZN Laser Zentrum Nord GmbH and parts of the Chair of Laser and System Technologies (iLAS) at Hamburg University of Technology were integrated into the Fraunhofer-Gesellschaft by resolution of the Senate as the newly created Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT, effective January 1, 2018. The decision was prompted by the outstanding scientific expertise that LZN and iLAS possess in the domain of 3D printing, which represents a valuable addition to the Fraunhofer-Gesellschaft's existing portfolio of institutes. Prof. Claus Emmelmann was appointed Director of Fraunhofer IAPT. Having already presided over LZN, he will ensure management continuity.

– As the first step toward integration into the Fraunhofer-Gesellschaft, a process begun in 2014, the former Mainz Institute of Microtechnology (Institut für Mikrotechnik Mainz GmbH) initially operated as a branch of the Fraunhofer Institute for Chemical Technology ICT. Following a successful performance evaluation in May 2017, the Senate has now decided to grant full institute status to this entity, which as of January 1, 2018 will operate as the Fraunhofer Institute for Microengineering and Microsystems IMM, based in Mainz, under the proven direction of Prof. Michael Maskos. Fraunhofer IMM carries out research in the fields of energy and chemical engineering, analytical systems, and sensor technology.

– Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner has stepped down from his position as member of the Executive Board of the Fraunhofer-Gesellschaft in charge of Finance, Controlling and IT at his own request after 15 years in office, effective December 31, 2017. The Senate ratified the early departure of Prof. (Univ. Stellenbosch) Dr. rer. pol. Gossner.

– As his successor, the Senate chose Andreas Meuer for a five-year term, commencing on January 1, 2018. In the newly created Executive Board function for Controlling and Digital Business Processes, Andreas Meuer will be responsible for the finances of the Fraunhofer-Gesellschaft and also for the far-reaching digitalization process in the Fraunhofer administration.

The Senate wishes to thank the Executive Board and all employees of the Fraunhofer-Gesellschaft for their commitment and successful work in the financial year 2017.

Prof. Dr.-Ing. Heinz Jörg Fuhrmann
Chairman of the Senate of the Fraunhofer-Gesellschaft

PROF. (UNIV. STELLENBOSCH) DR. RER. POL. ALFRED GOSSNER

Fraunhofer Vice President Finance, Controlling and IT from 2002 to 2017

After 15 years of service, Prof. (Univ. Stellenbosch) Dr. rer. pol. Alfred Gossner (67) left the Fraunhofer-Gesellschaft as of January 1, 2018 to go into retirement. Since taking up his position as Vice President Finance, Controlling and IT in 2002, he has made major contributions to Fraunhofer's outstanding development.

When he took over the reins from Dr. Ulrich Wiese, Alfred Gossner already had a well-filled career behind him. As assistant professor at LMU Munich, consultant at McKinsey and finally member of the Board of Management of Allianz Versicherungs-AG, he built up an extensive network, accumulated management and leadership experience, and acquired a deep understanding of how commercial businesses and scientific institutions work. Various periods of working abroad, such as his time as CEO of Allianz in South Africa from 1991 to 1995, also added to the experience of the father of two from Bad Grönenbach in Bavaria. Gossner maintained his close ties with South Africa and, in 2010, was awarded the title of Professor Extraordinary by the Business School at Stellenbosch University.

For 15 years, Alfred Gossner steered the financial fortunes of Fraunhofer as a highly esteemed partner for research funding agencies, employees, and government, business and scientific stakeholders. Optimizations kick-started by Gossner contributed to the lasting improvement of control structures and to the status of Fraunhofer. The Fraunhofer-Gesellschaft was also able to more than double its business volume over this period, particularly through the effective cooperation between institutes and headquarters. At the colloquium held in honor of Gossner's departure, Fraunhofer President Prof. Reimund Neugebauer thanked him for his outstanding achievements and expressed how he was looking forward to their continued cooperation in Gossner's new role as chairman of the board of the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation). Ilse Aigner, Bavarian Minister of Economic Affairs and Media, Energy and Technology and Deputy Minister-President of Bavaria, similarly praised Gossner's broad capabilities. As a parting gift, his successor Andreas Meuer presented him with a 10-year-old sequoia tree for his garden.

INSIDE THE FRAUNHOFER SENATE

At their annual assembly, the members of the Fraunhofer-Gesellschaft elect leading figures from the worlds of science, industry, business and public life to serve on the Fraunhofer Senate for a three-year term of office. Here we present profiles of newly elected senators.

REINER HOFFMANN

The incumbent President of the German Trade Union Confederation (DGB), Reiner Hoffmann, has been a member of the Fraunhofer Senate since January 1, 2018.

Born in 1955 in Wuppertal, Reiner Hoffmann started out his career as an apprentice at the chemicals company Farbwerke Hoechst. With a grant from the Hans Böckler Foundation, he studied economics at the University of Wuppertal. After completing his studies in 1982 with a degree in economics, he worked as an aide at the European Economic and Social Committee of the European Community in Brussels. From 1983 to 1994, he worked for the Hans Böckler Foundation in Düsseldorf, eventually heading up the Department for Research Promotion there. From October 1994 to May 2003, Reiner Hoffmann was Director of the European Trade Union Institute in Brussels; and from May 2003 to December 2009, he was Deputy General Secretary of the European Trade Union Confederation. From November 2009 onward, he was responsible for the collective bargaining and industrial policy for the North Rhine region in his capacity as North Rhine Regional Director of the IG BCE (Industriegewerkschaft Bergbau, Chemie, Energie) trade union, until he was elected to the National Executive Board of the German Trade Union Confederation (DGB) on October 1, 2013 and to the position of President of the DGB on May 12, 2014.

Reiner Hoffmann is a member of the German Social Democratic Party and of the IG BCE trade union. Since 2006, he has held a seat on the Supervisory Board of Bayer AG, Leverkusen.

"Social consensus has long prevailed on this point: new technologies require the continuous training of employees. The DGB and its member unions want to shape the future world of work. Accordingly, the unions support and participate in work research so as to guarantee good working conditions into the future. With its expertise and above all its practical orientation, the Fraunhofer-Gesellschaft is playing an important role in the digital transformation process. I'm very much looking forward to representing the voice of the unions in the Senate."

KERSTIN GROSSE

Kerstin Grosse joined the Fraunhofer Senate as of January 1, 2018.

As chair of the Supervisory Board, Kerstin Grosse represents KOMSA Kommunikation Sachsen AG, an information and communications technology (ICT) company specialized in distribution, services and new, connected, digitalized business processes. It is also the largest family-operated business in central Germany. In its parent company, Derossi Invest GmbH – with its four divisions of ICT; holding and investment management in a family office; agriculture; and forestry – Kerstin Grosse has been responsible for the Organization & Business Development unit since 2004. In 2006, she became chair of the Supervisory Board of Forestris AG.

Kerstin Grosse started her career at KOMSA in 1996 as PA to the CEO. In 1997, she took on a new role as company spokeswoman, and between 1999 and 2004 she was the Head of Human Resources.

Between 1992 and 1996, Grosse worked for the Deutsche Gesellschaft für Personalwesen e. V. (German association for HR management) in the field of recruitment and management/ organizational development for the public sector.

A native of Chemnitz, Grosse studied linguistics, educational science and psychology at Leipzig University, Voronezh State University in Russia and the University of St Andrews in Scotland, graduating in 1992 with a degree in pedagogy for adult education. While working, she also completed an MBA in customer relationship management at Chemnitz University of Technology between 2007 and 2009.

"Being elected to the Senate of the Fraunhofer-Gesellschaft is a great honor for me. I'm looking forward to representing the SME point of view, drawing on my professional background in this area. In times of growing digitalization and connectivity, small and medium-sized enterprises will be the object of research more than ever at Fraunhofer. Moreover, SMEs will be a major customer for Fraunhofer and an important part of its services."

OLIVER ZIPSE

Since the start of 2018, Oliver Zipse, member of the Board of Management of BMW AG, has been a senator of the Fraunhofer-Gesellschaft.

Born in Heidelberg in 1964, Zipse studied IT and mathematics at the University of Utah in Salt Lake City from 1983 to 1985. Between 1985 and 1991, he studied general mechanical engineering at the Technische Universität Darmstadt, obtaining a Master of Engineering (Diplom-Ingenieur) qualification.

In 1991, he started his career at BMW AG as a trainee in development, technical planning and production. From 1992 to 1994, he worked as a project engineer for technology development. In the years between 1994 and 2006, he held various management positions in development, manufacturing and production scheduling in Munich and South Africa. While working, he obtained an Executive MBA from WHU Koblenz and the Kellogg School of Management in Evanston, Illinois. From 2007 to 2008, he headed up the company's Oxford plant in the UK; and from 2009 to 2012, he headed the Technical Planning department, before being named Senior Vice President Corporate Planning and Product Strategy in 2012. On May 13, 2015, he was appointed to the Board of Management of BMW AG, with responsibility for Production.

"As a car manufacturer, we know very well that research and innovation are the fundamental basis for competitiveness in our industry. Only through innovations that offer customers genuine added value can we remain viable in the future. Many of the innovations in our vehicles owe something to the expertise of partners such as Fraunhofer. For this reason, I'm very much looking forward to my duties in the Fraunhofer Senate."

REVIEW OF FRAUNHOFER RESEARCH

REVIEW OF FRAUNHOFER RESEARCH

WORK IN A DIGITALIZED WORLD

Prof. Wilhelm Bauer, Prof. Ina Schieferdecker

We are in the midst of a digital revolution. The opportunities and risks that arise from this upheaval are endlessly appraised. For example, the industry association Bitkom warns that 3.4 million jobs will be lost in Germany over the next five years, because robots or algorithms will be doing the work. What people often overlook when numbers like this are being bandied about is that change brought about by technological progress has long been a constant in the history of our economy and our society. New technological developments have always transformed job profiles and work environments. And these changes have tended on the whole to improve the quality of work and the quality of life. Fraunhofer research has played a role in bringing about these positive developments. It helps us re-imagine and expand our conceptions of "work" in the digitally connected world. Technology is already a huge part of our society today. And this will accelerate and intensify as digital connectivity advances: robotics, virtualization, artificial intelligence (AI) and more are already transforming how we live and work today – and this will continue in the future. Long-established methods and processes will be swiftly modernized and revolutionized through digitalization. Even a traditional sector like agriculture has already been highly automated and digitalized. Soon, no egg or grain of wheat will make it to wholesalers or retailers without the assistance of sensor systems and data analytics. Other industries such as the media have already experienced major upheaval, while yet others such as the automotive sector are facing major challenges now – from e-mobility and multimodal mobility services to self-driving vehicles.

The driving force behind all these developments is the world of data. As a part of software, it is neither easy to grasp nor tactile in any way. Via visualizations and automated decisions and controls, data is being used in increasingly critical processes, such as production and traffic control. Throughout the spreading data economies, questions about the role, values, ownership, and usage rights of data will become centrally important. With automatable work increasingly being taken over by connected machines equipped with AI, and with data becoming increasingly important as a resource and asset, this also changes the role of work and its place in society. Companies, democracies and social systems must all adapt and develop to grasp the opportunities while also shaping the changes in the economy and society so that they benefit everyone.

Everyday life and work are changing

The increasing "intelligence" of systems and machines are changing how humans interact and coexist with technology. The car is a good example, with the digital transformation so far advanced in this sphere that assistance systems are accepted unquestioningly almost as equals alongside the driver. This acceptance may be partly due to the fact that the technology works quietly in the background, supporting us discreetly yet decisively as the situation demands it. This trend is set to continue: In the "EMOIO" project, for example, scientists at the Fraunhofer Institute for Industrial Engineering IAO are working with partners to research a brain-computer interface, via which future assistance systems could react directly to the driver's emotions. On the first inner-city digitally connected protocol route in Berlin, meanwhile, researchers at the Fraunhofer Institute for Open Communication Systems FOKUS are studying how automated driving systems can make everyday traffic safer for all road users. They are investigating complex cooperative driving functions, with which a group of vehicles can be coordinated and act in a predictive manner.

A precondition for such systems is a robust and reliable perception of the road situation. In the "RobustSENSE" project, Fraunhofer FOKUS has worked with industrial partners to develop a software platform that combines various sensor data from cameras, lasers, radar and even weather information.

Trustworthy, secure and reliable digitalization

Just as digitalization is revolutionizing "driving," so it is transforming the world of work. On farms, in factories and in offices, technical systems are now performing so many routine tasks that we only notice them when they break down. Accordingly, Fraunhofer is working not only on developing new technological solutions, but also on ways of rendering them secure. In the Eclipse Foundation's "IoT Testware" technology project, researchers from Fraunhofer FOKUS are working with industrial partners to develop standardized test solutions for IoT components in relation to conformity, interoperability, robustness and security. In addition, industrial partners can use the Transfer Center IoT run by Fraunhofer's Berlin Center for Digital Transformation for direct experience and experimentation. Additional security analyses and certifications are offered by the German Federal Office for Information Security in conjunction with Fraunhofer FOKUS. And recently the Fraunhofer "Certification 4.0" project was launched to research the further development of the testing processes and certificates themselves.

Progressive automation of work

With the further spread of the Internet of Things (IoT) and of Industrie 4.0, our everyday working lives will change dramatically. As systems become increasingly intelligent in how they operate, soon they will be taking over not just simple, monotonous tasks, but will become "digital colleagues." In office work for example, self-learning systems will perform accounting tasks or evaluate specialist journals. This will leave the human office workers with more time for more complex activities. Companies and researchers in the "SmartAIwork" project are currently investigating how AI and learning systems can ensure that the work handled by the machines is performed in a way that is entirely helpful to the respective human employee.

In production, too, digital "enablers" are reducing the time and cost needed for workaday tasks. With their further development and elaboration into "cyber-physical systems" (CPS), machines, systems, products, warehouses, tools and company IT will all learn to communicate with each other (despite their different interfaces) – and of course with employees, too (despite their different personalities). This will make production much more efficient, flexible and customized, as the tools will adapt automatically to the needs, skills and preferences of the individual worker and the task at hand.

If companies are not just to take a leap into Industrie 4.0, but also to land safely, they must make the right decisions from the outset: How do they want to advance their business using digital technology? What is the ultimate goal? How much would they have to invest in technology and IT – and at what stage? Where should they begin? A special "DigiCheck" offered by Fraunhofer IAO provides important guidance about the opportunities and risks facing small- and medium-sized

enterprises for their own business model. And Fraunhofer researchers are working with SME Industrie 4.0 pioneers to develop and test the tools that will then be needed to accomplish the digital transformation. One such initiative is the "ScaleIT" project, in which the partners create practical, scalable solution concepts that facilitate swift, targeted digitalization in production environments thanks to low entry barriers.

In the connected factory of the future, a product blank – whether for a sneaker or a car – is an autonomous cyber-physical system from the beginning. To this end, it is connected to a so-called asset administration shell, via which it can communicate with each relevant station on the production line. The "OpenIoTFog" Industrie 4.0 software from Fraunhofer FOKUS creates and manages these administration shells. To do this, it integrates industrial network standards, such as the TSN (time-sensitive networking) standard from the IEEE, and communication standards, such as oneM2MD. Reprogramming the production equipment is no longer required. The blank itself contacts the helpers it needs for completion, and it knows how it has to be processed.

A high-performance connection is the technological basis for all cooperation in Industrie 4.0. Blanket infrastructure coverage with data transmission rates in the gigabit range and tactile Internet with maximum availability, reliability and security and minimum response times are indispensable. The main foundation for this will be the new 5G mobile wireless standard, in the development and standardization of which Fraunhofer FOKUS and Fraunhofer HHI are playing a major role. One of the outstanding features of 5G is that it enables much more than a further development of "classic" mobile wireless capabilities. The launch of 5G will provide the first-ever network technology that combines wireless networks and fixed entryways in a virtualized, software-based environment. Future 5G infrastructures will ensure a dynamically configurable network that also incorporates decentralized computing resources. The above-mentioned administration shells can be flexibly stored and processed in the places where they are used – that is, in the factories themselves, on the "edge" as it is called. For this edge computing, TU Berlin and FOKUS developed the "OpenBaton" open-source software as a reference implementation of the ETSI NFV standard.

Synthesis of two worlds

The digitalized world generates a plethora of information about products and production, but also about the requirements and wishes of customers and of the employees working in factories. Evaluating and correlating the data this generates while observing all data protection requirements will be a key aspect of industrial value creation in the future. To utilize this potential, companies need to recognize and understand what individual opportunities and also what threats the onward march of digitalization means for them in concrete terms. Only on the basis of this knowledge can they develop a digital agenda to put their company "on course." Practical support is available to companies through the Digital Business Innovation initiative and the Fraunhofer Big Data Alliance.

Companies need a well-founded digitalization strategy before they can use the opportunities of the digital transformation. This strategy should be on three levels: Firstly, considerable efficiency potential can be exploited in production and administration – from real-time demand forecasting in retailing to the energy- and job-optimized control of whole factories. Secondly, making production more flexible creates the conditions for the individualization

REVIEW OF FRAUNHOFER RESEARCH

Work in a digitalized world

of products. In the "Mass Personalization – Toward a Business-To-User (B2U) Model with Personalized Products" initiative, the Stuttgart-based Fraunhofer Institutes for Industrial Engineering IAO, for Interfacial Engineering and Biotechnology IGB, for Building Physics IBP and for Manufacturing Engineering and Automation IPA have pooled their expertise in this area. And thirdly, digitalization presents additional market opportunities. After all, the digital world is not about replacing our products and services, which are world market leaders in many sectors; rather, the data from the connected world will enable us to enrich successful concepts by adding new value creation elements and to bring entirely novel ideas to the market.

The digital transformation will radically change companies. Only agile businesses will be able to compete in markets that are becoming more flexible. The success of this approach is demonstrated by start-ups, which tend to be highly dynamic in their structures. They are particularly successful in many of the new digital niches. Cornerstones of this "new agility" are flexible working models and greater scope for employees to pursue innovative ideas. In other words, digital transformation requires companies to create, trial, implement and embrace a new work culture. This does not mean completely abandoning tried-and-tested structures – rather, we need both. In this spirit, Fraunhofer IAO has developed a range of concepts that enable companies to remold their leadership style and organizational structures so that they are fit for the future. The name of the game is ambidexterity: organizational structures that are "two-handed" and companies that can work in agile and traditional ways at the same time.

It is equally vital for employees to have suitable further education and training in digital skills. According to the industry association Bitkom, 19 percent of German companies experience IT attacks at least once a week. To detect and prevent possible cyber attacks and guarantee control over security-relevant IT processes, private companies and public-sector organizations need strong IT security expertise. Targeted further education courses are offered by the Fraunhofer Cybersecurity Training Lab – which is funded by the German Federal Ministry of Education and Research – at its five locations as well as by the Fraunhofer Academy.

And last but not least, public-sector administration also has to keep up with these developments and respond to the challenges of digitalization in society and the economy. To this end, Fraunhofer FOKUS has set up the Competence Center Public IT (ÖFIT) to carry out research into the functions, infrastructures and further development of public IT.

New economic systems, new business models

Digitalization not only accelerates the development dynamics of traditional and new markets, but the technologies and products developed as a result also lead to far-reaching, sometimes disruptive changes in their own right. A characteristic feature is that many commercial and production structures struggle to respond successfully to the new developments. This is not a new phenomenon: the upheaval caused by the emergence of the large Internet platforms in sectors such as the book trade and mail-order selling should be fresh in our minds.

In the shade of these disruptive developments, however, new structures can often grow. Innovative economic systems in the platform economy and the sharing economy will thus represent an opportunity for German business – provided that the companies seize it and actively shape the development of markets before it is too late. The conditions in Germany are good to make this possible: the close connection between large corporations and SMEs has been a key success factor in our economy for decades. New market platforms offer a wide

range of structural possibilities – not only in the retail trade but in the B2B sector, too. Companies can connect with each other via open, neutral data and service marketplaces in order to generate new business ideas or link up their existing data to create value-added services.

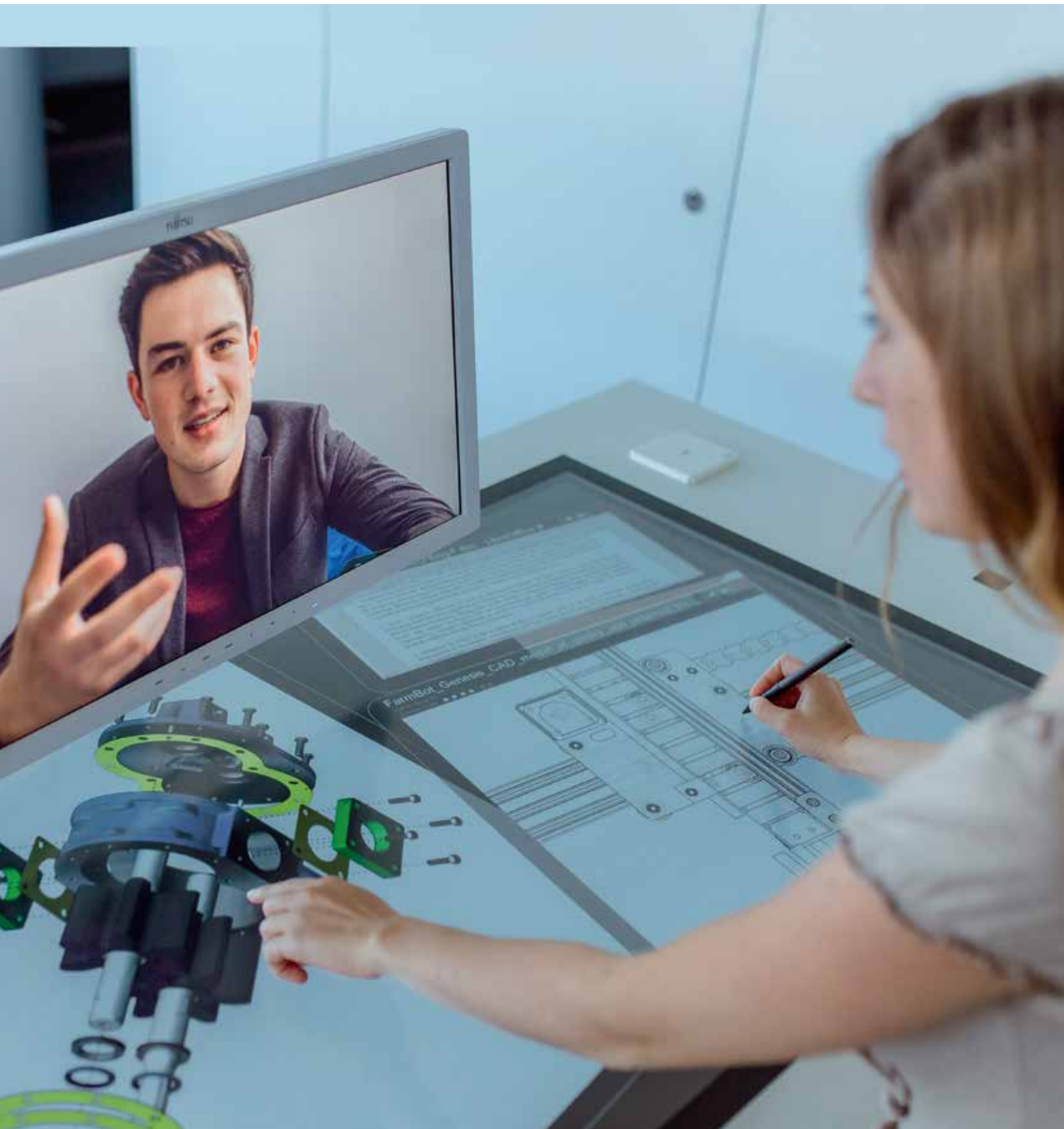
These approaches are supplemented by public sharing initiatives. A current publication by ÖFIT explores the example of smart mobility to show how platform-mediated sharing makes new service offers possible, whereby private vehicles, public transportation, ridesharing, carpooling, taxi services and car rentals all go hand in hand. The sharing of goods and services at the commercial level is also possible. An example of a practical implementation of this opportunity was developed by the partners in the "eMobility-Scout" project: using a cloud-based platform, companies can conveniently share their own charging infrastructure for electric vehicles with other companies in a way that profits all parties.

Connected value creation systems such as these, along with co-developments with universities and the research sector and open innovation laboratories, allow companies to combine tried-and-tested expert knowledge with a pioneering digital spirit to create shared digital innovations. In this way, they can utilize cultural and technological differences as joint resources, counterbalance their own weaknesses, offset the digitalization pressure and even transform it into positive opportunities for change. In the ARENA 2036 research factory, for example, researchers from Fraunhofer and the University of Stuttgart work with companies to develop and trial technology and organizational solutions for the entire value chain of the fully digitalized automobile.

Many sectors need to rethink their conventional ways of doing business and establish new Industrie 4.0 models. For example, this might involve putting together new service bundles comprising physical products and complementary real-time services. However, many companies do not yet possess suitable methods and the specific knowledge that would allow them to evaluate such concepts and the attendant risks. To help these companies, measures such as the "GEN-I 4.0" collaboration between Fraunhofer IAO and the ESB Business School at Reutlingen University provide businesses with support in transforming their business models for Industrie 4.0.

Flexible connectivity for more effective work

Working where and when you want is a dream for many people. Moreover, the technical conditions to make this possible have been around for years. Since its foundation over 20 years ago, the OFFICE21® innovation network has been continuously implementing concrete application solutions for its partners. Particularly in the area of knowledge and office work, this is helping establish a growing flexibility as regards working hours and locations. More and more employees are supplementing their work in the company office with work in a home office. This generally benefits both the employees and the company, as it makes for a more harmonious balance between work and private life. In addition, companies obtain greater flexibility in how they organize and schedule work. So that organizations can actually realize these benefits, they require individual concepts for effective implementation. In a study of mobile working, Fraunhofer IAO collaborated with the Institute of Human Factors and Technology Management IAT at the University of Stuttgart to investigate what the important factors were. Meanwhile, the "KapaflexCy" project shows that even in production contexts, mobile communications are able to provide a better equilibrium between the work-life



balance needs of workers and the increasing market-driven flexibility needs of manufacturing: using an app, shift managers and workers coordinate their working schedules and requirements in a fast, flexible and easy process.

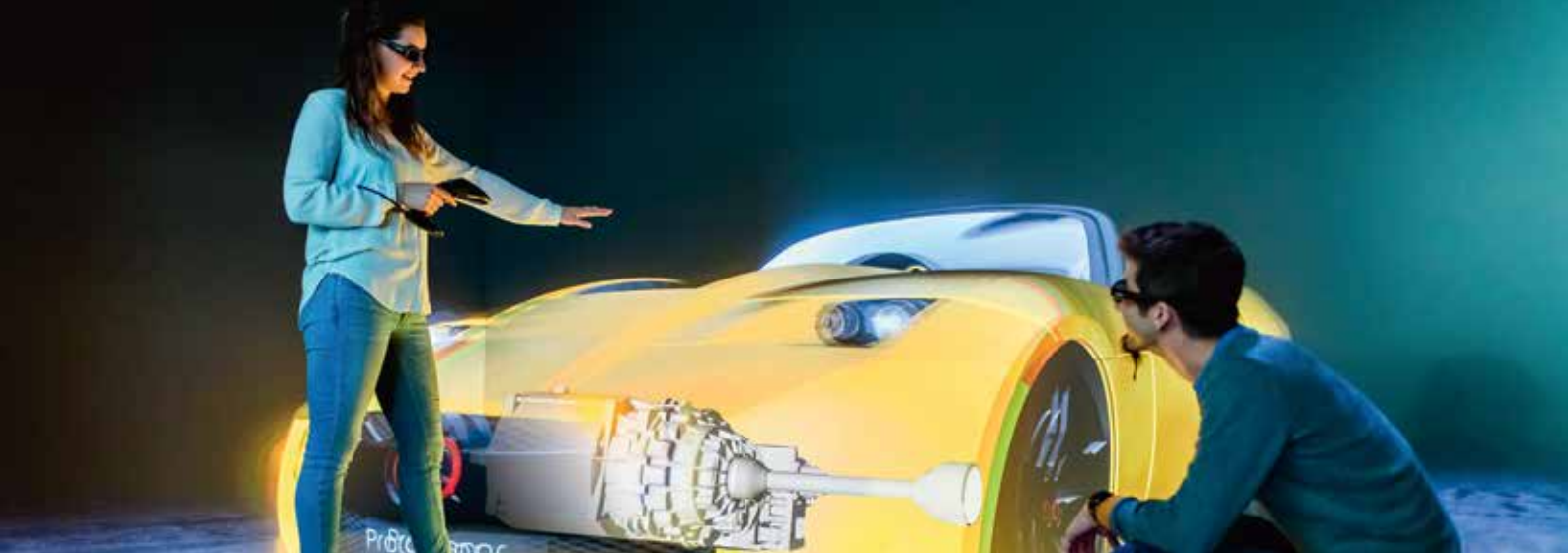
Comprehensive changes in work organization and forms of work are becoming particularly apparent in the area of knowledge work. The most conspicuous development is that experts from different sectors and disciplines will be able to cooperate more intensively in future. Increasingly, the place they choose to do this collaborative work is neither a home office nor the company office: instead, they meet up in so-called coworking spaces. These venues offer a place for independence and creativity, while also offering workplaces with optimum technical performance, including basic services such as lighting, heating and cleaning. The "Coworking – Driver of Innovation for Companies" study published by Fraunhofer IAO shows how companies can benefit from project work outside their premises. Temporary work environments offer ideal conditions for undertakings of this nature, in particular for crowd-workers, click-workers and digital nomads. This cohort of specialized freelancers will grow in number Germany-wide and internationally as the digital transformation of companies progresses. The advantage for companies of these "experts on demand" is that they can fetch the technical know-how and experience they require into their teams as and when required.

Digitalization that works for people

Free places in resident elderly care facilities must sometimes be left unoccupied because of a lack of qualified staff. And Germany's aging demographics are set to exacerbate the problem: the working population is declining, while the group of over-65s in Germany will increase to over 22 million people by 2030. Although care is mainly defined by human-to-human interaction, a lot of hopes are now being placed in the digital transformation, which can make a decisive contribution to easing the work burden on care staff. As part of the Work and Care 2020 innovation campaign, Fraunhofer IAO is developing innovative work and cooperation models. As well as focusing on professional care, the campaign also considers the situation of private individuals who combine looking after relatives with their working lives. This kind of double burden already affects every tenth employee in Germany.

How digitalization can support our health system on a wide variety of levels is the topic of the Telehealth Innovation Center at Fraunhofer FOKUS. At the center, researchers develop and test innovations such as new cooperation platforms via which care workers, doctors, patients and family members can connect and coordinate with each other. One of the researchers' main focuses is on the development of specific security architectures. Other focuses include an electronic patient file, which facilitates the exchange of medical data between doctors and ordinary citizens by various technical routes, and electronic case files.

Assistance robotics is a further technological priority, which is transforming human work on wards in care institutions and hospitals and is set to ease workloads considerably in the future. In the "SeRoDi" project, for example, researchers from Fraunhofer IPA and Fraunhofer IAO are working with the University of Stuttgart and other partners to develop a self-driving nursing cart. This will replace old-fashioned "shoe leather logistics" by relieving nursing staff of long walks back and forth along corridors and wards. In turn, this saves them time and physical energy. For example, a care robot can fetch medical supplies autonomously from the storeroom and carry them to where they are needed.



The new role of workers

What work will remain for us humans when connected systems, smart machines and robots carry out more and more tasks in offices and factories? The fact is that human labor is no longer required for a variety of monotonous routines and physically demanding jobs. Fundamentally, this must be viewed as progress – even if certain jobs are partially or wholly abolished as a consequence. For example, it can alleviate the effects of the shortage in skilled labor. Furthermore, we will not run out of work, as the digitalized world also needs humans. However, the type of tasks we carry out will change, becoming more sophisticated and varied; there will be a general shift away from four-square manual labor toward activities that involve planning, controlling, creative thinking and supervision. But the digital transformation to Industrie 4.0 and the IoT will also be a huge undertaking for employees in every single company. After all, it is not some ready-made technology concept, but an ongoing development that each company must approach individually.

The question remains as to what the next steps might be for companies to successfully begin their journey into the age of Industrie 4.0. At all events, it is vital that their employees possess suitable digital knowledge and skills. Companies can find answers about the requisite competencies and expertise, as well as useful further training measures, through initiatives such as the "FutureKomp 4.0" guidelines drawn up by Fraunhofer IAO and the Institute of Human Factors and Technology Management (IAT) at the University of Stuttgart. In addition, the "New Work" project utilizes concrete case studies to allow businesses to learn from companies that have already progressed further down the road toward Industrie 4.0. And finally, the Future Work Lab, which opened in the spring of 2017, makes it possible to experience future concepts for Industrie 4.0 and tomorrow's world of work today. With its Demonstrator World for the work of the future, the "Fit for the work of the future" Learning World, and the World of Ideas for work research, the lab offers an ideal platform for exciting dialog and intensive cooperation between science, industry and society. Another important research instrument for the digital transformation is the Weizenbaum Institute for the Networked Society, which was founded recently in Berlin-Brandenburg and counts Fraunhofer among its members. The interdisciplinary research conducted by the Weizenbaum Institute focuses on the social changes that accompany the forward march of digitalization, and the question as to how self-determination can be safeguarded in a connected society.

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AGENDA 2022 – NEW TOPICS, STRUCTURES AND INSTRUMENTS FOR FRAUNHOFER RESEARCH

Prof. Reimund Neugebauer, Dr. Raoul Klingner

What prompted the Fraunhofer 2022 Agenda

The Fraunhofer-Gesellschaft wants to continue fulfilling its clearly defined mission of carrying out excellent research that is geared systematically toward practical applications. To do this, it must face new challenges, including the increasing complexity of globally connected value chains and the penetration of the digital transformation into many areas of the economy and society. In this environment, Fraunhofer wants to structure its own growth such that both productivity and value creation increase quantitatively, and new qualities are generated in the form of disruptive innovations. To achieve these goals, as well as energetically pursuing specific research topics such as the transition to a new energy economy and e-mobility, it also needs to pursue with equal vigor broad technological trends such as digitalization and the biological transformation. Against this background of dynamic change, and with a view to maintaining Fraunhofer's worldwide leadership position among contract research organizations into the future, the Executive Board of the Fraunhofer-Gesellschaft worked with the Presidential Council and the institutes to develop a joint roadmap – Fraunhofer 2022 Agenda. This development plan describes the essential change processes for Fraunhofer from today's perspective and the corresponding implementation projects with a horizon of 2022.

The goals

As Fraunhofer 2022 Agenda is systematically based on the Fraunhofer-Gesellschaft's mission, its general goals seek to increase the impact of its activities on the economy and society through excellence and synergy. Equally, the Agenda incorporates the vision of the Fraunhofer Guiding Principles, namely to implement system-relevant initiatives for Germany. The strategies required for this are designed to intensify internal collaborations through new governance and management methods and expand the corresponding research and transfer infrastructures. At the same time, Fraunhofer 2022 Agenda strives to increase quality in essential overarching topics that either help secure Fraunhofer USPs – such as the transfer of R&D results into applications – or contribute to increasing performance – such as collaborations with external partners.

Agenda 2022 – new topics, structures and instruments for Fraunhofer research

The Fraunhofer 2022 Agenda operationally implements the new Fraunhofer Guiding Principles.

Focused portfolio planning with new topics

When planning its research portfolio, Fraunhofer pursues an approach whereby individual plans are created at institute level before undergoing a structured comparison at the Fraunhofer Group and corporate levels. This model facilitates the decentralized embrace of a wide variety of research trends, market developments and social challenges while also enabling the systematic harmonization of the overall portfolio and the generation of synergies through internal cooperation.

Fraunhofer operates through 72 institutes and possesses more than 400 core competencies in the sphere of research and development (R&D). Accordingly, it is predisposed like no other applied R&D organization to form interdisciplinary teams through internal collaborations and develop comprehensive system solutions for current issues. Fraunhofer had already undertaken such initiatives occasionally in the past. Now this process is to be further professionalized and reinforced through the Fraunhofer 2022 Agenda. To this end, Fraunhofer is pursuing its own system-relevant initiatives (Key Strategic Initiatives – KSIs).

To identify and select such initiatives, Fraunhofer employs a quality-assured search process that takes into account both implicit and explicit sources. Following an evaluation and structuring of topics, initiatives that are deemed suitable are incorporated into the Fraunhofer 2022 Agenda. Their goal is either to obtain a leading scientific position, generate significant industrial revenues or amplify perception of the topic among society at large.

The Fraunhofer 2022 Agenda currently contains 7 Key Strategic Initiatives:

1. Battery technology / battery cell production
2. Cognitive systems / data sovereignty
3. Programmable materials
4. Quantum technology
5. Translational medicine
6. Public safety and security
7. Biological transformation

In order to utilize the maximum synergy potential for the implementation of the Key Strategic Initiatives, it is necessary to adapt the Fraunhofer research and transfer structures as well as cross-institute thematic and project management.

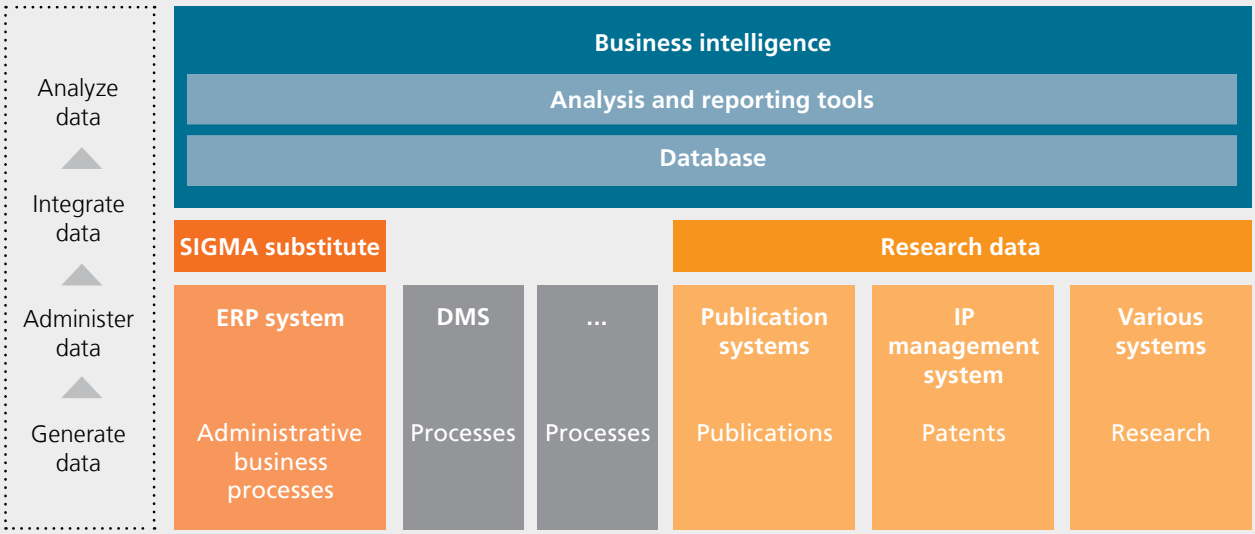
New research and transfer structures

Fraunhofer has established a series of internal programs that pursue different funding objectives. The new "Cluster of Excellence" instrument was created to support the internal cross-institute development of system-relevant topics. Importantly, these research clusters are founded not just to implement an individual project, but to pursue a comprehensive roadmap for the development of a complex topic. Organizationally, the research cluster – spread as it is over several locations – is equivalent to a "virtual institute."

The Research Fab Microelectronics Germany (FMD) is already practicing such a model: that is, a virtual institute with a connected research infrastructure. In 2017, the German Federal Ministry of Education and Research (BMBF) granted Fraunhofer a substantial investment sum to bring its technological infrastructure in the field of microelectronic manufacturing up to the state of the art. In order to successfully realize the establishment of such an integral research factory spanning a total of eleven subject-specific Fraunhofer Institutes and two Leibniz Institutes at the various locations, a new cross-institution organizational structure is needed in addition to the financial investment. Therefore, new innovation and transfer processes are developed within FMD and controlled via an institute-independent office (one-stop shop), so that effective and efficient cross-institute process and value chains can be organized and established.

In addition to the two new internal research infrastructures described above, Fraunhofer is also further developing the High-Performance Centers it launched in 2015. These Silicon-Valley-like alliances with university and non-university partners and local businesses have a strong regional profile and work on topics of the future such as Smart Production, Electronic Systems and Photonics at a single location in an application-focused manner. This involves the creation of joint transfer roadmaps for the coordination of research and teaching, continuing education and training, and innovation and transfer. For example, joint international courses of study have already been set up and spin-offs have received comprehensive support. These spin-offs have been able to bring new technologies to market in the protected and integral environment of a High-Performance Center. As of 2018, the network of positively evaluated High-Performance Centers is to form the nucleus for the establishment of a long-term national transfer infrastructure – analogous to the established Max Planck Schools for developing new scientific talent.

Overview of Fraunhofer Digital



Fraunhofer Digital and its three project components: Data is acquired from diverse sources in the Fraunhofer data space. At the same time, Fraunhofer processes are being modernized and comprehensively automated through the substitution of the existing ERP system. In parallel, business intelligence tools can be developed to integrate and analyze the data.

Fraunhofer Digital

As a leading research organization, Fraunhofer is at the forefront of the global digitalization trend, advancing technologies in various fields of application, such as manufacturing. It is thus imperative for Fraunhofer to utilize the digital potential of its own data. As part of the Fraunhofer 2022 Agenda, administrative and research data are to be linked, aggregated and analyzed in order to optimize research and development processes and support management decisions at institute and central levels. This comprehensive project employs various data acquisition and utilization methods and techniques that Fraunhofer already offers to public-sector and industrial clients in state-of-the-art services. In this way, it is possible to carry out processes – especially collaborations between institutes – more efficiently and, furthermore, to develop new data utilization business models for external organizations.

New project and thematic management

In view of topics such as e-mobility, Industrie 4.0 transformation and the transition to a new energy economy, Germany is facing complex technical-scientific and also structural challenges with high economic and socio-political relevance. For Fraunhofer, this means that its work increasingly requires a systemic approach. Companies need a research partner that considers long-term perspectives and can carry out research on a cross-disciplinary basis. Therefore, a wider approach to project and thematic management is required both for the orchestration of Key Strategic Initiatives and for strategic collaborations with global companies. For example, large projects currently underway are being analyzed in terms of their structures, processes, instruments and resources in order to derive new recommended actions for issues such as incentives, controlling, governance and qualifications. With this expanded management tool, Fraunhofer has gained the necessary credentials to operate on an equal footing with its industrial partners when it comes to implementing large-scale, system-relevant projects.

Alongside the management of individual major projects, an additional challenge is that of orchestrating the collaboration between multiple Fraunhofer Institutes on a broad R&D topic. The aim here is to conceptualize a complex topic in the light of Fraunhofer's expertise, develop a suitable roadmap, connect the internal and external players, set up the corresponding R&D projects, and finally to evaluate the results jointly. To do so, the present system of corporate portfolio management needs to be revised by assigning strategic management prerogatives to the Executive Board and in this way facilitating the effective and efficient organization of cross-institute coordination.

Stronger cross-institute coordination through more intensive corporate management.

Agenda 2022 – new topics, structures and instruments for Fraunhofer research

Gender-neutral paths to career excellence

Family-friendly structures and processes that guarantee equal opportunities for outstanding young scientists of both sexes are essential if an R&D organization aims to attract the best talent. Therefore, Fraunhofer has set itself the goal of further increasing the proportion of female scientists and particularly of female managers it employs. In a project to promote gender-neutral paths to career excellence, selected female scientists are given guidance to prepare them for future positions as professor or chair of a university department. In this case, a personalized career plan is elaborated with the institute where the scientist works, and central support is also provided for the strategic structuring of cooperation agreements with potential universities. This project is accompanied by an individual career program.

Revenue-oriented start-up strategy

Among the various transfer routes within Fraunhofer, spin-offs that benefit Germany as a home of innovation are accorded particular importance. For example, on a long-term average, the number of Fraunhofer spin-offs has been increasing and, in individual cases, substantial revenues have been generated in the past from licensing agreements and exits. In the future, spin-offs and exits are to be further developed through the systematic use of existing and new methods. Alongside established funding formats for founders of spin-outs and support from the internal Venture Group, Fraunhofer wants to achieve an increase in the spin-off rate and higher industrial revenues from spin-offs in the medium-term, particularly through the implementation of suitable transfer structures for SMEs and by opening up to external start-ups.

International collaborations based on Fraunhofer policy

International activities and collaborations with global R&D partners have long been part of Fraunhofer's core business. This activity has grown into a complex web of consortium projects, strategic collaborations, project centers abroad and autonomous Fraunhofer subsidiaries. This network has to be constantly recalibrated and realigned with Fraunhofer's goals. To facilitate this focus, Fraunhofer is currently elaborating a new internationalization strategy with the twin goals of setting out strategies for cooperation with the highest-caliber international partners and qualitatively bolstering its own institutionalized commitments abroad. In this way, the realignment will also lay down clearly defined criteria and models for the interaction of international Fraunhofer organizations with the German institutes.

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Dr. Raoul Klingner is Director of Research at the Fraunhofer-Gesellschaft headquarters.

Structure of the Fraunhofer 2022 Agenda

The Executive Board and committees of the Fraunhofer-Gesellschaft continuously supervise Fraunhofer 2022 Agenda, monitor the objectives of the implementation projects and adapt them dynamically according to current requirements. In combination, the transparency of Agenda 2022 and the dialog with stakeholders will ensure that in the future, Fraunhofer will continue to play a significant role in the sustainable development of Germany's economy and society.

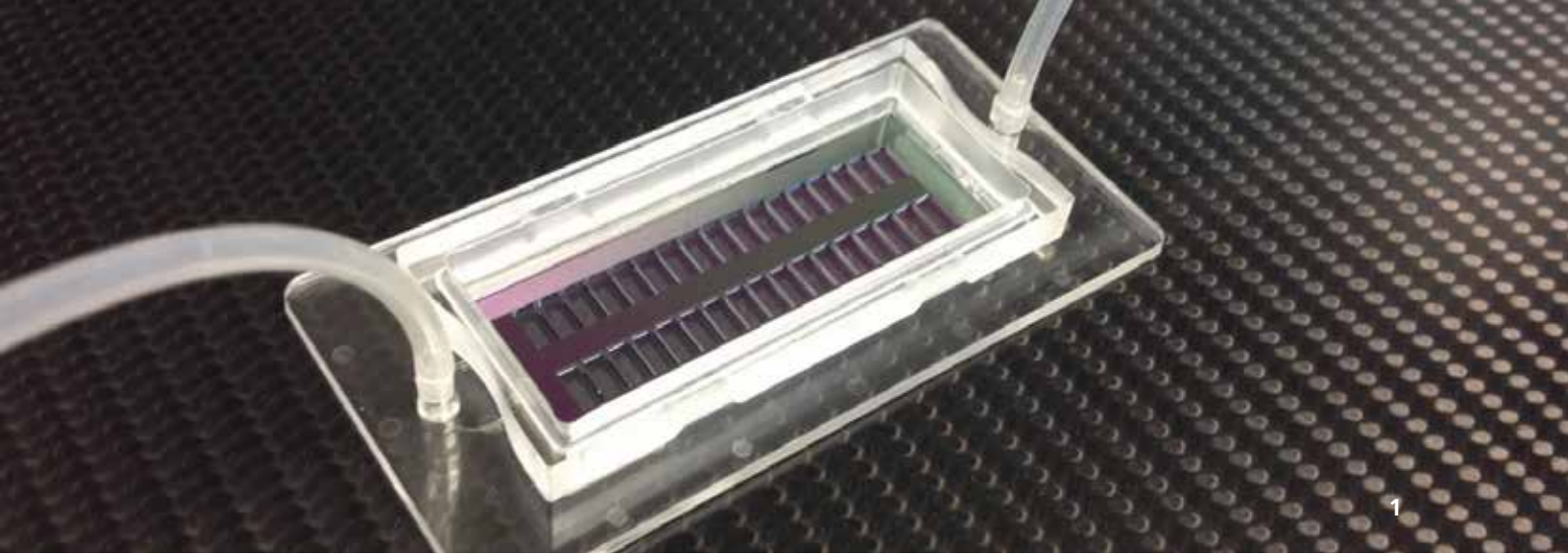
HEALTH AND ENVIRONMENT

Biodegradable electronics

If a patient needs a temporary medical implant, they generally need to go under the knife twice: once to put in the implant, and a second time to take it out again. Under the leadership of the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP, Fraunhofer researchers are now working on a way to render this second operation unnecessary, by developing electronic components that fully dissolve after a defined period. This kind of technology has advantages that are not limited to medical engineering, but also include the development of environmentally friendly products. The researchers are developing the main components for such biodegradable electronics – including the conductor paths, electrode contacts and thin-film transistors.

Focus on individual cells 1

Is a cancer treatment having the desired effect? An indicator for this is the number of tumor cells that travel through the blood. Moreover, the more tumor cells existing in the blood, the greater the danger of metastasis. Before now, however, it has only been possible to estimate the number of these circulating tumor cells very roughly – the method commonly used quickly reaches its limits, and it is unable to record all tumor cells due to a lack of markers. A new microhole chip from the Fraunhofer Institute for Biomedical Engineering IBMT, by contrast, effortlessly captures up to 200,000 cells from a blood sample. Within a few minutes, the cells slide individually onto a hole, where they are suctioned and fixed in place by a slight negative pressure. The cells thus lie neatly one beside the next as if served up on a tray. In this way, they can be characterized and removed unharmed for further analytical steps. Using this technology, doctors will be able to determine why a drug works or fails to kill the tumor cells. Moreover, a whole range of other applications are conceivable for the new microhole chip.



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Joseph von Fraunhofer Prize

Effective wastewater treatment

Without water, there is no life. Effectively, this means that wastewater has to be efficiently cleaned and reused, by means such as ceramic membranes. Before now, however, this technology ceased to work at molecule sizes of 450 Daltons, being unable to separate out molecules smaller than this. Experts even believed it impossible to go below this threshold. Dr. Ingolf Voigt, Dr. Hannes Richter and chemist Petra Puhlfürß from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS have now made the "impossible" possible. They succeeded in lowering the cut-off to 200 Daltons for the first time – thereby achieving a whole new level of quality in filter membranes. This was made possible through advances in the sol-gel technique. The scientists successfully scaled up the membrane synthesis for production and fitted out a pilot plant in Alberta, Canada. The membrane surface is 234 square meters. Since 2016, the plant has been purifying wastewater that is generated during the production of petroleum from oil sand. For this work, the scientists were awarded the Joseph von Fraunhofer Prize.

Fight against infectious diseases

Infectious diseases are yet again a growing threat. Numerous germs have already developed a resistance to conventional antibiotics – in such cases, treatment is ineffective. New therapies must therefore be found. However, many pharmaceutical companies fear treatments developed will prove to be unprofitable. As a result, many potentially effective substances fall by the wayside on their journey from discovery to finished drug. This is where the iCAIR project comes in – a collaboration between the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM, Hannover Medical School (MHH) and the Institute for Glycomics (IfG) at Griffith University on Australia's Gold Coast. iCAIR wants to close the gap in the development chain – the laborious step from the laboratory to clinical trials – so as to clear the way for new kinds of active ingredients. The research alliance thus develops new treatment options for various infectious agents – from the identification of therapeutic target structures to the preclinical proof of concept.

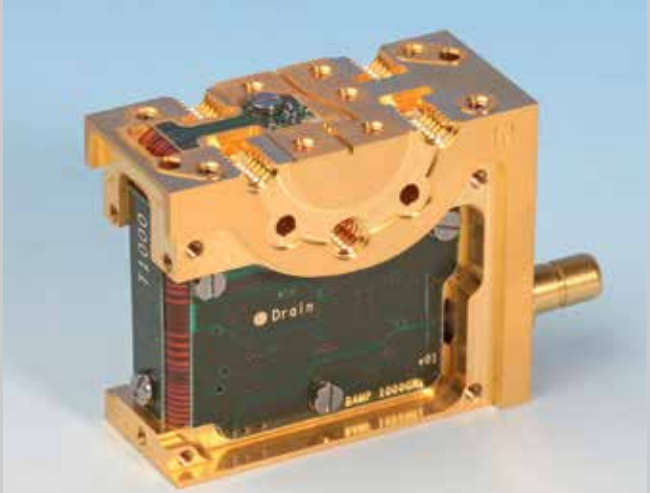
1

Protein drink made from lupines 1

Whether out jogging, cycling or at the gym: When you come home, you crave a drink that is refreshing, delicious and reinvigorating. But it should not contain too many calories. A new lupine protein drink is just the ticket. It resembles a cool whey beverage with carbon dioxide added. Purely plant-based – and thus vegan and lactose-free – it supplies the body with valuable proteins. Because the lupine extract has a relatively neutral taste, many different aromatizations are possible. But the lupine plant is not just rich in proteins, it also contains undesirable phytic acid, which binds valuable minerals and inhibits enzymes. To solve this problem, researchers at the Fraunhofer Institute for Process Engineering and Packaging IVV have developed a technique that preserves the proteins during the processing of the sweet lupines, while also strongly reducing the phytic acid. This is made possible by a combination of malted cereals and special microorganisms. The manufacturing process is similar to brewing beer and uses apparatus which can be found in any brewery, such as a mash tun, a lauter tun or a fermentation tank. Accordingly, big additional investments are not required.

Alternative to animal testing

The flu virus is constantly changing, making it necessary to review and adapt the composition of the flu vaccine every year. Doing this has frequently involved animal testing, which is performed on ferrets and other animals worldwide. Together with colleagues from other research institutions, researchers at the Fraunhofer Institute for Cell Therapy and Immunology IZI, Bioanalytics and Bioprocesses Branch in Potsdam, now want to change this in a project entitled "FluType: Development of an influenza sub-classification platform based on peptides." Their goal is to develop a fast in-vitro analysis method for the vaccine tests, thereby avoiding animal experiments. This is made possible by small protein sections known as peptides, which are fitted on a biochip and can help distinguish the various flu strains from each other. Another advantage of the technique: The sub-classification of the influenza viruses should only take a few hours – instead of several weeks as was previously the case. In October 2017, the research team in Berlin received an award and prize money of 25,000 euros for their alternative methods to animal testing in research and education.



2

COMMUNICATION AND KNOWLEDGE

Weather forecasting with microwaves 2

For weather forecasts, meteorologists rely on computer simulations fed by data provided by thousands of satellite measurements. Accordingly, the better the sensors on board the satellites, the more precise the measurement values – and therefore the more accurate the weather forecasts. Over the next two years, the European Space Agency (ESA) will launch into space the second generation of its MetOP (Meteorological Operational) weather satellites, which are able to record important meteorological variables better than ever before. At the heart of these measurement devices are extremely sensitive microwave amplifiers, which were developed at the Fraunhofer Institute for Applied Solid State Physics IAF. These amplifiers capture microwaves that are emitted by water vapor, rain, fog and ice crystals – particularly the ice crystals contained in cirrus clouds high up in the atmosphere. Moreover, the temperature on the ground can be extrapolated very precisely from the microwave radiation.

Augmented reality in the operating theater

Malignant tumors often form metastases, which spread throughout the body via the lymph node system. Determining the exact position of such nodes and removing them completely requires a lot of skill on the part of surgeons. Was the entirety of the affected lymph node actually removed? A navigation aid by the Fraunhofer Institute for Computer Graphics Research IGD is designed to make the procedure easier for surgeons in the future: 3D-ARILE is an innovative augmented reality system which takes the form of data glasses. Displayed on the glasses, doctors see directly the exact position of the lymph node. What makes the system really special is that the AR glasses are combined with high-performance software for medical navigation along with a stereo system made up of near

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infrared (NIR) cameras and indocyanine green (ICG) fluorescent dye. The glasses are very light and comfortable to wear, as dermatology doctors at Essen University Hospital confirmed after numerous tests.

CT for musical instruments 1

Is the violin still playable? In what condition is the pianoforte? And the basset horn – what shape is that in? 3D X-rays can provide a unique insight, revealing information about how an instrument was made, its body, hidden repairs, possible damage such as cracks, and much more. In the MUSICES project, researchers at the Fraunhofer Development Center X-Ray Technology EZRT, a division of the Fraunhofer Institute for Integrated Circuits IIS, used 3D computed tomography to peer inside historical musical instruments from the collection belonging to the Germanisches Nationalmuseum (GNM). Measurement standards on how best to examine old musical instruments using 3D computed tomography have yet to be established. To remedy this situation, the researchers are collaborating with specialists from the GNM in Nürnberg and the Chair of X-ray Microscopy at the Julius-Maximilians-Universität in Würzburg to draw up guidelines. This will enable museums worldwide to digitalize all different kinds of instruments with comparable image quality.

Joseph von Fraunhofer Prize
Clear voice on the telephone

It often seems as if smartphones can do everything. However, there is one thing that remains substandard: voice quality during phone calls. This is set to change with the Enhanced Voice Services (EVS) standard. Instead of hearing a muffled and distorted voice on the other end of the line, the other person sounds as clear and as natural as if you were talking face to face. The new codec was initiated and developed by the 3rd Generation Partnership Project (3GPP), the international body that publishes standards for mobile communication. One of the major participants in the project was the Fraunhofer Institute for Integrated Circuits IIS in Erlangen. Instead of simply cutting off the audio signal beyond a frequency of 3.4 kilohertz, as previous standards do, EVS transmits the full audible frequency spectrum – at data rates comparable with existing mobile phone codecs. The Joseph von Fraunhofer Prize for 2017 was given to Markus Multrus, Dr. Guillaume Fuchs and Stefan Döhla for the development of the EVS codec. They accepted the prize on behalf of the 50-strong team who worked on the project.

2

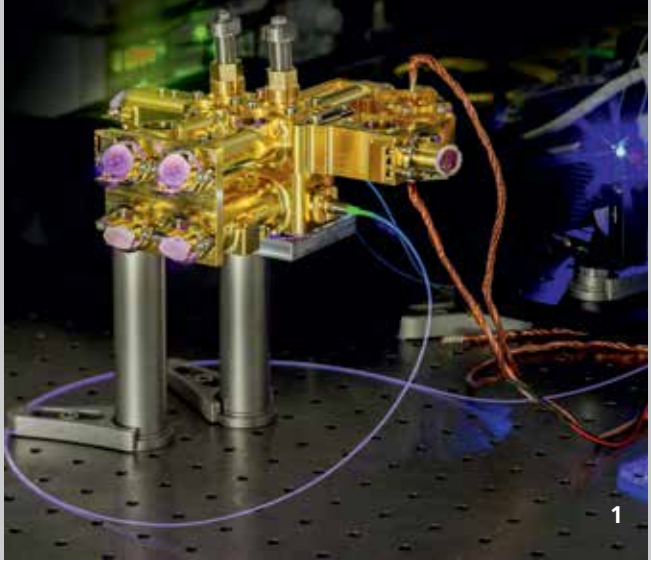
Hugo Geiger Prize

Transparent electrodes for displays 2

What would our modern information and communications technology be without active photonic components, such as flat screens, LEDs and OLEDs? Key parts of all these components are transparent coatings that are also conductive. These are often referred to as transparent conductive oxides (TCOs). However, indium tin oxide, which is used for these TCOs in most commercial products, is very expensive. In her doctoral thesis, Dr. Astrid Bingel at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF created TCOs based on zinc oxide which exhibit a wide variety of transparency ranges and electrical conductivities. In addition, she developed a material system that contains an intermediate layer of silver just a few nanometers in thickness and offers a promising alternative to the commercially used indium tin oxide. The manufacturing technique is established, straightforward and can easily be scaled up for industrial production. For her dissertation, Astrid Bingel was awarded the 2017 Hugo Geiger Prize.

Higher performance through cooling

If a processor gets too hot, it throttles the clock speed and operating voltage. As a result, the computing speed falls or the processor switches off completely, in order to protect the CPU and mainboard from heat damage. Cooling is therefore an important factor when it comes to computing power. A team of researchers at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin and Dresden has now found a way to cool microchips not just from the top, but also – for the first time – from the bottom, using a fluid-based cooling system. This allows heat to be carried away more effectively and leads to higher performance. To do this, microchannel structures with hermetically sealed vias are installed in the silicon interposer, which is located between the processor and the printed circuit board. Coolant is then pumped through the microchannels, drawing harmful heat away from the processor. In addition, the scientists integrated passive components for voltage regulators, photonic ICs and optical waveguides into the interposer.



1

PROTECTION AND SECURITY

Certainty with quantum mechanics 1

So that data does not fall into the wrong hands, it is encrypted – usually using mathematical techniques. However, the processing power of computers is growing rapidly, making it ever easier to decode encrypted messages. Developments like the quantum computer could even render current methods of encryption obsolete. Coding with entangled light quanta offers a solution to this problem. Researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF are now taking a major step in the direction of secure communication. They are developing a quantum source that permits the transmission of entangled photons from satellites. Special keys can then be generated based on this quantum source: Senders and receivers can recognize at a glance whether third parties have tried to intercept or manipulate them. The telecommunications industry has already shown interest in this robust solution.

Fight against human trafficking

Human trafficking – often coupled with sexual exploitation – remains a huge international problem. The victims are often underage girls and boys smuggled over the border by people traffickers who supply them with false ID documentation stating they are of legal age. A technological solution to tackle this kind of passport fraud would allow the authorities to be much more effective. With the PRIMSA mobile ultrasound hand scanner, researchers at the Fraunhofer Institute for Biomedical Engineering IBMT have now developed such a technology in the multidisciplinary research project PRIMSA (prevention and intervention in sex trafficking). The technology uses ultrasound scans to analyze bone formation in the wrist. It takes 18 years for the growth plates in the radius and ulna bones to ossify fully in women, so that their existence is

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an indicator for immaturity. Accordingly, this provides a quick means of identifying underage women when there is a suspected case of passport fraud. Because the ultrasound measurement technique is non-invasive, it can be used without the court order generally required for X-ray analyses.

Joseph von Fraunhofer Prize

Support for senior citizens

Now that the proportion of elderly people in our society is growing a care bottleneck looms on the horizon. Moreover, many people want to be able to live independently in their own home well into old age. This is only feasible, however, with efficient new care approaches that quickly recognize emergencies, organize suitable help if necessary, and ensure continuous support and consultation. Cornelius Moucha, Mario Schmitt and Rolf van Lengen from the Fraunhofer Institute for Experimental Software Engineering IESE have collaborated with Anne Gebert from the German Institute of Applied Nursing Research and Bernd Klein from CIBEK technology + trading GmbH to develop and test an IT platform that makes this possible. Using self-learning software that updates itself continuously, the platform registers personalized behavioral patterns – and thanks to non-invasive technologies, residents do not notice a thing. Via a user-friendly communication platform, users can also make contact with other senior citizens or with care workers. The system has already been successfully tested in a two-year trial conducted in the Greater Trier area; further application possibilities are currently being developed. For this research achievement, the partners won a 2017 Joseph von Fraunhofer Prize.

Remedies for space junk 2

Earth's orbit is a busy place. Numerous satellites zip around, providing smooth telecommunications, transmitting TV signals, and supplying data for navigation, weather forecasts and climate research. However, a serious threat is posed by uncontrolled objects, such as decommissioned or damaged satellites, pieces of space stations and the remains of space missions. If they crash into a satellite, it will not only be destroyed, it can also break into thousands of new pieces of debris – a dangerous snowball effect. Experts at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF have developed a laser system that allows the position and direction of travel of objects in Earth orbit to be reliably determined with centimeter precision. A laser developed by Fraunhofer IOF, which is able to withstand the inhospitable conditions in Earth orbit, forms the centerpiece of the system. The system has already been tested successfully during a docking maneuver of a spacecraft to the International Space Station (ISS). But space junk can also be precisely located from the ground thanks to the TIRA space observation radar from the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR. This radar is unique in Europe and holds several world records for its technical performance.

1

Hugo Geiger Prize

Malware quickly detected

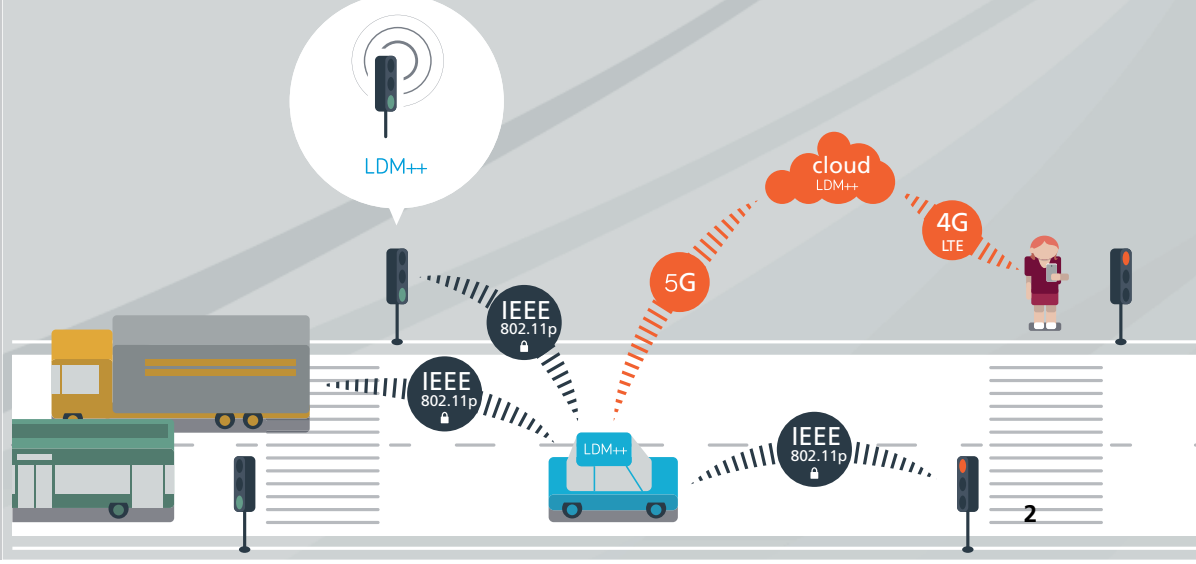
The media carry stories almost every week of cyberattacks, in which hackers spread malware. These attacks threaten businesses, government institutions and private individuals alike, and time and again they cause great damage. A particularly risky scenario is if malware is hidden in software products, where ordinary anti-virus protection programs have scarce chance of finding it. Before now, the operators of app stores had great difficulty in automatically identifying disguised malicious apps. In his dissertation, Dr. Siegfried Rasthofer from the Fraunhofer Institute for Secure Information Technology SIT supplied new approaches designed to detect and investigate malware in apps. This even works in cases when hackers disguise the malware. Among other things, his doctoral thesis gave rise to the licensable CodeInspect software, which is offered by Fraunhofer SIT. For his work, Rasthofer was awarded a Hugo Geiger Prize for 2017.

Stability during earthquakes 1

Around the world, heavy earthquakes regularly convulse whole regions. They often lead to fatalities, because many of the homes in the affected areas are not earthquake-proof. Together with industrial partners, researchers at the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI are therefore developing building materials that could save thousands of lives. Engineers at Fraunhofer WKI are currently working on ultra-durable bracing that will protect even high-rise buildings during an earthquake. Taking the form of so-called moment connectors, the bracing is designed for buildings with post-and-beam structures. These connectors join the horizontal beams or joists to the vertical posts – and permit deformations. In the case of an earthquake, this means that although the houses start to vibrate, they do not collapse. Numerous tests have already demonstrated that the moment connectors work as expected.

Avalanche: danger from infected systems

Avalanche was the largest botnet infrastructure in the world. Over many years, it caused millions of euros' worth of damage by infecting computer systems with malware. A team from the Cyber Analysis & Defense department at the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE played a major role in the Avalanche takedown at the end of 2016. It supplied the German Federal Office for Information Security (BSI) with technical support for understanding the infrastructure, analyzing the malware and warning the victims. Since then, Fraunhofer FKIE has operated so-called sinkhole servers together with BSI. They replace the criminals' former control servers and prevent computers infected with Avalanche malware from being reused for illegal purposes. In this way, affected users are identified and notified. As a result, the number of infected systems worldwide was reduced by 45 percent in 2017; in Germany, there was an even greater reduction of 61 percent.



MOBILITY AND TRANSPORTATION

Infrastructure for mixed traffic 2

A car that motors past you without a driver? This is set to become reality on roads all over the world. In the INFRAMIX project, researchers from eleven European companies and research institutions are developing an expanded road infrastructure. It will take into account both vehicles driven by humans and vehicles controlled by computers. First of all, various traffic scenarios – such as a road narrowing as it approaches road works – will be tested in simulations, before being evaluated on test routes in Austria, Spain and Germany. Researchers at the Fraunhofer Institute for Open Communication Systems FOKUS also took part in the project. Among other things, they developed a connected Local Dynamic Map (LDM++), which will be installed in both the virtual and the real trials. LDM++ links a high-precision digital map with current data from the environment, such as the speeds of nearby vehicles, and further sensor information.

Safely through road works

Road works are not exactly popular among motorists: the lanes narrow, tailbacks build up, and many drivers feel stressed or uncertain about what to do. However, the systems in automated vehicles are also quickly overwhelmed by this complex situation. The sensor systems find it difficult to register traffic signs and cones, and the signs often contain divergent information about the allowed speed. A technology by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS now enables self-driving systems to read such signs with a high degree of accuracy. To do this, it uses an automotive camera that currently supplies 20 to 25 pictures per second. With deep learning – a key technology for the future of the automotive sector – the researchers teach the software

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to recognize the traditional patterns more quickly and effectively. As a result, freeway exits that are signposted differently due to road works can be correctly interpreted, the distances to other vehicles can be optimally measured, and the vehicle's speed can be adjusted on time. It is envisioned that this camera may act as a primary interface in the future, rendering many sensors unnecessary.

Data logger for mobility research 1

Our mobility is now changing rapidly. Trends such as electro-mobility, autonomous driving and carsharing are transforming our driving behavior and opening up new markets of the future. But how are the vehicles actually used? This question is answered by a data logger developed by the New Drive Systems project group at the Fraunhofer Institute for Chemical Technology ICT, enabling new generations of automobiles to be adapted to the driving behavior of the individual. The data logger is fitted into a car over several weeks and months. During journeys, it saves all relevant operating data, helping researchers create usage-specific evaluations. Scientists combine several users into user groups and evaluate that driving data on a group-specific basis. A unique feature of the data logger is that it is flexibly configurable: its use is not restricted to conventional vehicles with IC engines. This versatility makes the technology interesting for industrial partners. The first collaboration has begun with an international original equipment manufacturer (OEM), where the logger is already being used in the conceptual design of hybrid vehicles. Another possible field of application is the management of vehicle fleets.

Battery for 1000 kilometers

Today's electric cars don't get you very far. One reason is that the batteries take up a lot of space, greatly limiting the number that can be used. Under the trade name EMBATT, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS in Dresden has collaborated with ThyssenKrupp System Engineering and IAV Automotive Engineering to transfer the bipolar principle, which is familiar from fuel cells, to the lithium battery. In this approach, individual battery cells are not lined up separately beside each other in bitty arrays but are placed directly over each other in large stacks. As a result, the whole casing and contacting structures are no longer required, and more batteries fit into the car – increasing its range. Initial tests in the laboratory were successful. As the next step, the researchers are planning to develop larger battery cells and install them in electric cars. For the medium term, the project partners are targeting ranges of 1000 kilometers for electric cars with the installation concept.

2

3

Joseph von Fraunhofer Prize

Solution to chromium ban 2

If components need to be protected against corrosion and wear, they are often given a coating that contains chromium(VI). Since September 2017, however, the environmentally harmful technique is permitted only with special authorization. This ban presents industry with huge challenges. Dr. Andres Gasser and Thomas Schopphoven at the Fraunhofer Institute for Laser Technology ILT in Aachen and Gerhard Maria Backes at the Chair for Digital Additive Production (DAP) at RWTH Aachen University have developed a cost-effective alternative: extreme high-speed laser material deposition, known by its German acronym EHLA. The method is cost-effective, resource-efficient and environmentally friendly, as it does not use any chemicals. Another advantage of EHLA is that heat-sensitive components can now be coated for the first time. This brings completely new material combinations into the realms of the possible. For their work, the researchers were awarded a Joseph von Fraunhofer Prize for 2017.

Hybrid storage system with market potential 3

How about an energy storage device that charges in seconds, has a large capacity and a long lifetime? Many have dreamed of just such a device. In the FastStorageBW II project, researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, working with counterparts from the battery manufacturer VARTA Microbattery GmbH and other partners, have now gone ahead and developed one. The high-performance hybrid storage system combines the advantages of an NiMH battery and a double-layer capacitor: the PowerCaps have a specific capacity approximately as high as lead-acid batteries, and with over 20,000 charge cycles (50 percent DOD), they offer a long service life; also, they charge almost as quickly as supercapacitors – that is, in a few seconds. In addition, they can be used up to a temperature of 85°C, and they retain their charge for several weeks – without any notable losses through self-discharge. The Fraunhofer research is devoted primarily to production engineering. It optimizes manufacturing processes that are suitable both for small batches and for the series production of PowerCaps, and designs them for the needs of Industrie 4.0 from the outset.

1

PRODUCTION AND SERVICES

Hugo Geiger Prize

A new vision for image sensing 1

Before incoming light strikes the pixels of an image sensor – in a digital camera for instance – an optical filter breaks it down into the primary colors of red, green and blue. Currently, these filters are made out of organic polymers. However, there are limits to how small these filters can be made, and they also age through exposure to UV rays and heat. In his dissertation, Dr. Maximilian Rumler at the Fraunhofer Institute for Integrated Systems and Device Technology IISB studied plasmonic filters, which offer an alternative to the color filters generally used today. What plasmonic filter structures are most suitable for image sensing? Using the Dr.LiTHO simulation program created by Fraunhofer IISB, he calculated spectral filter behavior and investigated the influences of various factors. In addition, he reduced the computing time required for the simulation. Furthermore, he optimized the embossing technique employed in substrate conformal imprint lithography and used it for the first time to manufacture large-area plasmonic filter structures. In this way, Rumler was able to show that photonic structures in the nanometer range can potentially be produced cost-effectively. For his work, he was awarded a Hugo Geiger Prize for 2017.

2

Reliable production

If a machine suddenly breaks down during production, it not only drives up the costs, but also impacts on delivery reliability, which ultimately reduces a company's competitiveness. And yet the problem is often caused by relatively small defects or signs of wear, which initially remain undetected but later lead to bigger failures and production stoppages. In the SelSus project (short for Health Monitoring and Life-Long Capability Management for Self-Sustaining Manufacturing Systems), researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA are developing a new kind of system. It monitors the status of machines and components, recognizes weaknesses and signs of wear at an early stage using intelligent software and sensor networks, and predicts failures. The diagnostic method they developed also gives tips on how the problem should be solved. Project partners Electrolux in Pordenone (Italy) and the Ford engine plant in Dagenham (UK) are already using the SelSus system. With this practical trial, Fraunhofer IPA and the project consortium have demonstrated that the technology also works reliably in practice.

Joseph von Fraunhofer Prize

Holography in production 2

Sometimes every thousandth of a millimeter counts – as exemplified by components for the automotive or aviation industries. The challenge is to verify during production whether the individual components are fault-free and true to size. Before now, there was no method for checking this at second intervals and with the required accuracy. To remedy this deficiency, three researchers at the Fraunhofer Institute for Physical Measurement Techniques IPM – Dr. Markus Fratz, Dr. Alexander Bertz and Dr. Tobias Beckmann – have now taken the method of digital holography out of the laboratory and into production – for which they received a 2017 Joseph von Fraunhofer Prize. They removed all previously existing drawbacks of the interferometric technique and developed a system that for the first time allows micrometer-precise measurements during the production process. It captures data on raw components a centimeter in size across their whole surface in fractions of a second and offsets interfering factors such as vibrations. In addition, it is the fastest system available on the market worldwide for high-precision three-dimensional measurements.

Marker-free tracking

Production flows are closely connected, and supply chains are global. For industrial companies, this makes it difficult to trace the individual components of complex products post manufacture. However, efficient track and trace solutions are an important condition for production and process optimization – particularly in the context of Industrie 4.0. Now the Fraunhofer Institute for Physical Measurement Techniques IPM has developed Track & Trace Fingerprint, a marker-free system for tracking mass production components. To do this, the technology uses the distinctive microstructure of the surfaces of components and semi-finished products – effectively a sort of "fingerprint" of the individual objects. Even with batch sizes of several hundred thousand units, these fingerprints can be uniquely identified by the second, which allows component-related data to be reliably assigned during the production cycle. Additional markers or IDs on the product are not required. Consequently, the system is not only counterfeit-proof, but also very economical to implement because costs are not dependent on quantity.

1

Heat-resistant ultrasonic transducers

If there are cracks, corrosion or other flaws in a component – such as the steam pipes in coal-fired power stations – they need to be repaired urgently. Ultrasonic sensors fitted to the outside of the components are able to detect such defects. However, they only work on components that are not hotter than 200°C. Researchers at the Fraunhofer Institute for Silicate Research ISC have now created piezo sensors for high-temperature applications for the first time. At the institute, the sensors have already been implemented at temperatures of up to 600°C. Generally speaking, temperatures of up to 900°C are possible. Additionally, the ultrasonic sensors remain stable over long periods – at least two years in any use case – and for many applications, researchers expect a service life of several decades. The principle is the same as for other piezo sensors – the challenge consisted in constructing the piezoelectric crystals so that they could withstand long-term use as sound transducers on hot components. Happily, the scientists were able to solve this problem by using heat-resistant glass solders, which they employed instead of the temperature-sensitive glue and housing material.

Bending sheet glass with the help of lasers 1

A new technique developed by the Fraunhofer Institute for Mechanics of Materials IWM makes it possible to bend sheet glass into complex or unusual shapes using a laser beam. This will pave the way for innovative new products in architecture and design in the future. For the technique, the researchers exploit the special characteristic of glass to become viscous and malleable at high temperatures. The rest is accomplished by exact calculations and the power of gravity. The laser-supported technique allows architects and industrial designers to make use of complex shapes that were previously very difficult and costly to produce. Here, sheet glass is shaped without the need for a bending mold to apply pressure. In this way, the new process doesn't leave behind any unsightly marks – the flat glass surfaces remain visually undistorted.

2

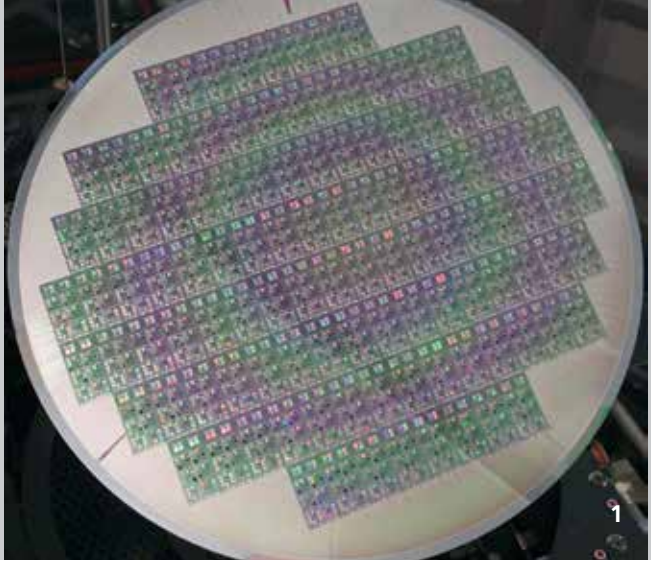
ENERGY AND RAW MATERIALS

Customized spectroscopy

Each chemical substance absorbs a distinct portion of infrared light. Like a human fingerprint, this specific absorption can be used to identify substances. Such methods are used in sectors as various as the chemical industry, the health sector and criminology. If a company is planning a new project, it often requires customized sensor solutions. In the EU-funded MIRPHAB Pilot Line, leading European research institutions and companies have joined forces to provide customers with tailored offers of this technology from a single source. Three Fraunhofer Institutes are involved: the Fraunhofer Institutes for Applied Solid State Physics IAF, for Photonic Microsystems IPMS and for Production Technology IPT. MIRPHAB offers solutions based on infrared semiconductor lasers, which possess much greater optical intensity. Capable of recording up to 1,000 spectra per second, these lasers can be used to automatically monitor and control chemical reactions and biological processes in real time, for example.

Energy in containers 2

How can an energy storage unit inside a container help industrial companies and larger building complexes receive a clean, secure supply of energy? This question is being investigated by the Fraunhofer Institutes for Integrated Systems and Device Technology IISB and for Integrated Circuits IIS together with experts at the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and regional industrial partners. At Fraunhofer IISB in Erlangen, the consortium is setting up a system for the compact seasonal storage of large amounts of energy. It is integrated into a modern DC microgrid. In this unique system, which is unlike any other in the world, all the components fit inside a 20-foot container. The project was developed within the High-Performance Center Electronic Systems (LZE).
Its basic concept involves generating hydrogen out of surplus



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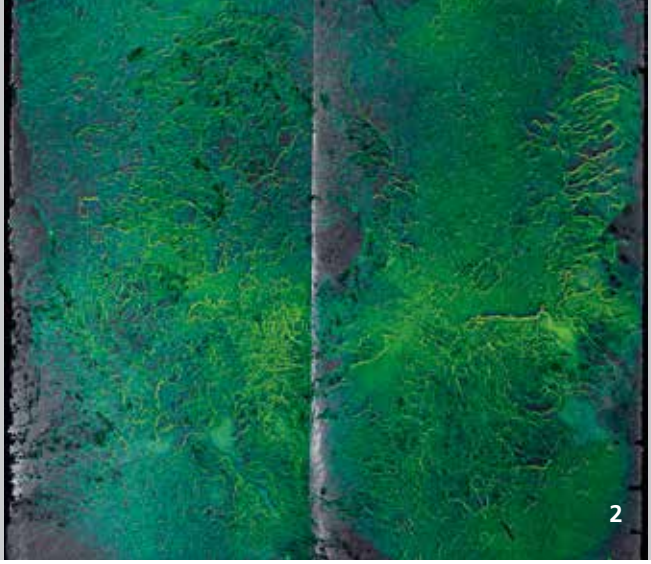
electrical energy (e.g. from a local photovoltaic plant) and storing it securely and compactly – over longer periods if required – in an organic carrier under normal environmental conditions as regards pressure and temperature. The maximum electrical charging capacity is 25 kilowatts. When subsequently required, the hydrogen can be released again from the carrier and converted into electrical energy using a fuel cell. Some 300 liters of LOHC can be stored in the tanks, which corresponds to an energy of almost 600 kilowatt hours locked up in the hydrogen. The storage quantity can be increased without limit by simply adding extra tanks.

Heat-resistant capacitors 1

Heat is one of the worst enemies of electronics. It can cause electronic components to malfunction, or age more quickly, and even destroy them. Fortunately, the Fraunhofer Institute for Microelectronic Circuits and Systems IMS has a solution to this problem. Its researchers have developed a capacitor that can withstand temperatures of up to 300°C, whereas conventional electronics can cope with temperatures of only up to 125°C. When manufacturing the conducting metal layers, tiny holes are etched into the baseplate in order to increase its surface area. This 3D approach increases the capacitance while also improving heat resistance. In addition, a new material mix of tantalum pentoxide – a compound of the metal tantalum and oxygen – is used. The metal oxide semiconductor (MOS) manufacturing technique developed by the scientists also brings advantages: It allows the processing of films of just one atomic layer in thickness, making production very flexible. The manufacturer can produce components exactly according to the customer's specifications without having to change the flow of the process.

Self-programming paint booth

Products of all kinds are becoming increasingly customized. Batch sizes of one are the long-term goal. As far as the painting process is concerned, however, companies still have major hurdles to overcome. Before now, automation and individualization of products have not gone well together when it comes to painting technology. In many industries, therefore, well over half of all components are painted by hand. The SelfPaint self-programming paint booth is designed to offer companies a solution to this problem for the first time – as well as providing a whole range of cost-saving opportunities. It is being developed jointly by the Fraunhofer Institutes for Manufacturing Engineering and Automation IPA and for Industrial Mathematics ITWM and the Swedish Fraunhofer-Chalmers Centre for Industrial Mathematics FCC. SelfPaint makes possible the automated painting of small batches and even individual pieces – and does so very efficiently: companies can save up to 20 percent on paint and reduce solvent emissions by 20 percent. In addition, SelfPaint requires 15 percent less energy and is 5 percent faster than the manual painting methods generally used to date. On top of this, the automated technique outperforms manual work in terms of reproducibility.



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Making the electricity yield predictable

Storm or calm, dark clouds or clear skies – depending on the weather situation, wind turbines and photovoltaic plants feed more or less electricity into the grid. This is a big challenge for the operators of transmission networks, who have to predict the amount of energy fed into the grid as exactly as possible in order to keep the networks stable. To help find a solution, the Fraunhofer Institute for Wind Energy and Energy System Technology IWES teamed up with Germany's national meteorological service, the Deutscher Wetterdienst (DWD), in the EWeLiNE project to develop mathematical models that allow significantly better predictions than conventional techniques. The project was successfully completed in May 2017. Practical tests show that the new forecasting models exhibit a very high level of prediction accuracy. A key aspect of the project consisted in adapting the weather models to the specific requirements and conditions of renewable energy sources. For example, the models now permit exact predictions of wind conditions at the height of wind turbine hubs. In addition, the platform can be used online.

The strength test 2

Wind turbines are supposed to be environmentally friendly, highly efficient and cost-effective – and also to work reliably for at least 20 years. However, as turbines become increasingly powerful, the the component stress grows, increasing the risk of material fatigue. Defects such as dross inclusions are undesirable, as they significantly reduce the ability of components to withstand stresses. As there has been no structural durability concept available now for reliably dealing with dross, foundries only approve dross-free products for use. In the “unverDROSSen” project, researchers at the Fraunhofer Institutes for Structural Durability and System Reliability LBF and for Nondestructive Testing IZFP have developed testing methods and dross strength classes for the purpose of detecting and modeling these inclusions and characterizing them in terms of their strength. Therefor they use mechanized ultrasonic testing for the volumetric exami-nation of components and use magnetic and electromagnetic methods to test machined component surfaces. Although each component will still have to be examined individually in the future, with the information provided by the nondestructive IZFP testing technologies and a component design concept for cyclic loaded components provided by Fraunhofer LBF, the manufacturer can now keep the amount of rework needed to a minimum or even release the component without rework.

NEW INITIATIVES AND INFRASTRUCTURES

Fraunhofer Clusters of Excellence

Virtual institutes for big topics

When research fields are growing in complexity all the time and yet need to be advanced quickly and with the requisite thoroughness, the proper answer to this challenge is virtual institutes – research communities that can achieve worldwide technological leadership with high capacities, swiftness and international visibility. Fraunhofer founded four such structures – "Clusters of Excellence" as they are called – in 2017.

Advanced Photon Sources

The vision of this Cluster of Excellence is to achieve world leadership in laser systems offering the highest power combined with the shortest pulses. Its defined research objective is to develop laser sources and beam shaping for laser powers greater than 5 kilowatts and pulse lengths from 100 to 1000 femtoseconds. In addition, applications of this technology are to be created for manufacturing and science. Above all, this requires advances in laser material processing, miniaturized X-ray lasers and XUV imaging. The Fraunhofer Institutes for Applied Optics and Precision Engineering IOF and for Laser Technology ILT are active members of the cluster, which is headed up by Prof. Reinhart Poprawe.

Immune-Mediated Diseases

This Cluster of Excellence pools together Fraunhofer's expertise in disorders of the immune system within a virtual institute for drug and therapy research. Its work is directed toward developing personalized drugs and therapies for dysfunctions of the immune system. Working together in the cluster are the Fraunhofer Institutes for Molecular Biology and Applied Ecology IME, for Toxicology and Experimental Medicine ITEM and for Cell Therapy and Immunology IZI, under the direction of Prof. Gerd Geisslinger.

Programmable Materials

This research cluster signals a paradigm change in the design process by integrating functionality directly into materials. Its defined research objective is to realize previously unobtainable functionalities by using materials that are dynamic in function or form, or composite materials, or surfaces that can be controlled in targeted ways or that can be altered in reversible ways. Among the institutes participating in the cluster are the Fraunhofer Institutes for Mechanics of Materials IWM, for Applied Polymer Research IAP, for Chemical Technology ICT, for Building Physics IBP and for Machine Tools and Forming Technology IWU. Prof. Peter Gumbsch is the director of the cluster.

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Cognitive Internet Technologies

Through this cluster, Fraunhofer wants to integrate the principles of learning and understanding – based on reliable, trustworthy data – directly into the system design of the Internet, so as to generate useful information from data in a controlled manner. It links the physical with the digital world, develops key technologies, and ultimately establishes technological leadership for the Cognitive Internet with a focus on Industrie 4.0 and mobility. The expertise is concentrated in three research centers: IoTCOMMs (trustworthy sensor systems), coordinated by Prof. Albert Heuberger; Fraunhofer Data Space (sovereign data space), coordinated by Prof. Boris Otto; and Informed Machine Learning, coordinated by Prof. Stefan Wrobel. Aside from the four Fraunhofer Institutes chiefly involved in the cluster (the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS, for Integrated Circuits IIS, for Software and Systems Engineering ISST and for Applied and Integrated Security AISEC), a further nine Fraunhofer Institutes are currently contributing to the cluster's work. Prof. Claudia Eckert is director of the cluster.

Lighthouse projects

Strategic topics for industry

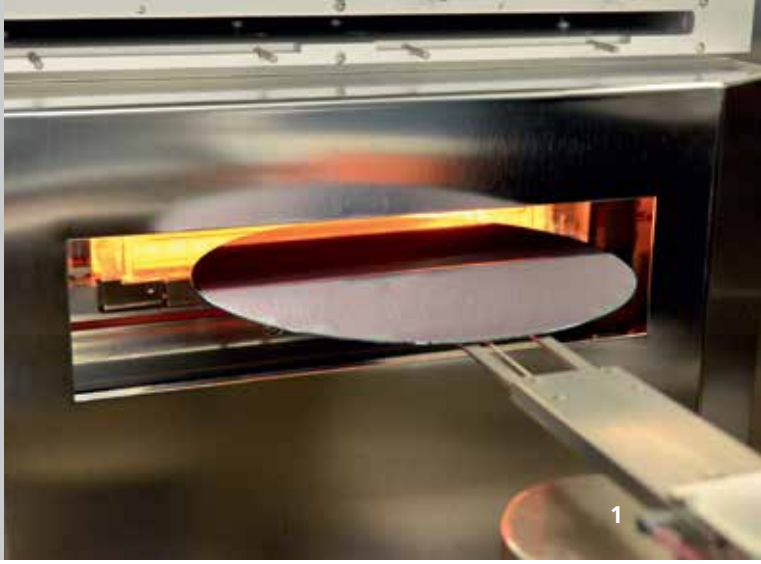
With its focus on applied research, Fraunhofer is always particularly close to business and industry. The idea behind the concept of lighthouse projects is to pool together outstanding expertise within the Fraunhofer-Gesellschaft for acute and future challenges facing industry. The objective of the lighthouse projects is to generate clear profiles inside the Fraunhofer portfolio by exploiting synergies. The project proposals approved in 2017 have the potential to strategically further expand Fraunhofer's thematic leadership in the corresponding subject areas in Germany and Europe for the commercial exploitation of ideas.

ML4P
Machine Learning for Production

In this lighthouse project, the consortium comprising the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS, for Factory Operation and Automation IFF, for Industrial Mathematics ITWM, for Mechanics of Materials IWM and for Machine Tools and Forming Technology IWU and led by the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB plans to develop a tool-supported process model and corresponding interoperable software tools. In this way, the data from a production system is to be recorded, expressed in formal terms and prepared for use in the machine learning method spectrum in order to detect existing optimization potential.

QUILT
Quantum Methods for Advanced Imaging Solutions 1

Under the leadership of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, the QUILT lighthouse project pools together quantum technology platforms and market knowledge from the Fraunhofer Institutes for Applied Optics and Precision Engineering IOF, for Physical Measurement Techniques IPM, for Laser Technology ILT, for Microelectronic Circuits and Systems IMS, for Optronics, System Technologies and Image Exploitation IOSB and for Industrial Mathematics ITWM and joins them with the scientific excellence of leading quantum technology institutions worldwide. The goal is to make the Fraunhofer-Gesellschaft the first port of call for quantum optics application solutions.



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ZEPOWEL
Towards Zero Power Electronics

The motivation behind this lighthouse project is the exponential increase in electronic devices, their connectivity and the associated rise in energy demand. Experts predict that the research will reduce energy consumption by a factor of 5; demonstrators are already in the planning stage. The lighthouse project benefits from the participation of the Fraunhofer Institutes and Research Institutions for Microsystems and Solid State Technologies EMFT, for Embedded Systems and Communication Technologies ESK, for Applied Solid State Physics IAF, for Integrated Circuits IIS – including the Branch Engineering of Adaptive Systems EAS – for Integrated Systems and Device Technology IISB, for Photonic Microsystems IPMS, for Silicon Technology ISIT and for Reliability and Microintegration IZM.

Go Beyond 4.0

The automation, digitalization and connectivity of high-volume industrial production are among the biggest challenges of the 21st century. Above all, companies operating in the burgeoning automotive, consumer electronics, manufacturing and lighting sectors need to retain the economic benefits of mass production in order to manufacture the customized products demanded by the market. The Go Beyond 4.0 lighthouse project, which is led by the Fraunhofer Institute for Electronic Nano Systems ENAS, marries traditional manufacturing methods with innovative technologies and digital production techniques. Digital printing and laser techniques will be used by the project consortium to customize mass-produced products. This will pave the way for the individualized design of series products in a resource-efficient and cost-effective manner, all the way down to one-of-a-kind items. The lighthouse project kicked off on February 10, 2017 and benefits from the involvement of the Fraunhofer Institutes for Electronic Nano Systems ENAS, for Manufacturing Technology and Advanced Materials IFAM, for Laser Technology ILT, for Applied Optics and Precision Engineering IOF, for Silicate Research ISC and for Machine Tools and Forming Technology IWU.

eHarsh
Sensor systems in extremely rough environments 1

The objective of the eHarsh lighthouse project is to develop and provide a technology platform that can be used as the basis for developing and manufacturing sensor systems for deployment in extremely rough environments. In this way, the consortium is addressing the rapidly growing demand for smart control and communication technologies – particularly in the "Mobility and Transport," "Energy and Raw Materials" and "Production and Services" research fields of special interest for Fraunhofer.

As part of the lighthouse project, the following technologies and expertise will be developed and provided:

- Robust sensors for use up to 500°C and MEMS sensors for use up to 300°C
- Integrated circuits and system components for use up to 300°C
- Hermetically sealed housings that also facilitate media access to sensors
- 3D integration and encapsulation at the system level (system-scaled packaging)
- Analytics and test procedures for various stress patterns, including combined loads
- Understanding the behavior of utilized materials with regard to the risk of defects and degradation mechanisms
- Expanded reliability analyses and models

2

The lighthouse project is seeking to establish Fraunhofer as the technological leader in the field of sensor systems for extremely harsh environments. Taking part in the project are the Fraunhofer Institutes for Electronic Nano Systems ENAS, for Ceramic Technologies and Systems IKTS, for High-Speed Dynamics, Ernst-Mach-Institut, EMI, for Laser Technology ILT, for Microelectronic Circuits and Systems IMS, for Physical Measurement Techniques IPM, for Microstructure of Materials and Systems IMWS and for Reliability and Microintegration IZM.

Project hubs

Strong research through cooperation

When applied research topics call for particular attention, the Fraunhofer-Gesellschaft seeks to strengthen the relevant research areas with project hubs, which allow several Fraunhofer Institutes to cooperate directly with other research institutions.

Energy storage and systems 2

Agreement has been reached to found a new hub for energy storage research in the German State of Lower Saxony. Involving close cooperation with Braunschweig University of Technology, the center will develop new solutions for batteries and fuel cells both for electromobility applications and for stationary battery systems. Advances are needed in these fields in order to realize new vehicle concepts, autonomous driving and alternative powertrain technologies. The strategic research field of mobility at Braunschweig University of Technology – represented by the Automotive Research Center Niedersachsen (NFF), the Battery LabFactory Braunschweig (BLB) and the Open Hybrid LabFactory (OHLF) – will be further strengthened by the project hub. On the Fraunhofer side, the Fraunhofer Institutes for Ceramic Technologies and Systems IKTS and for Manufacturing Technology and Advanced Materials IFAM are represented.

Microelectronic and optical systems for biomedicine

Health, demographic change and autonomy into old age are some of the biggest societal challenges of the coming years. It will only be possible to successfully manage them if players from business and science work closely together. The further development and linking of key technologies such as biosciences, microelectronics and optics and photonics are of particular importance here. For this reason, a new Fraunhofer Project Hub is being established in Erfurt, the capital of the German State of Thuringia. At the center, scientists from the Fraunhofer Institutes for Applied Optics and Precision Engineering IOF, for Photonic Microsystems IPMS and for Cell Therapy and Immunology IZI will carry out research on interdisciplinary approaches for biomedicine in close cooperation with partners from business.

High-Performance Centers

The fast track from ideas to applications

With its creation of the first High-Performance Centers in 2015, the Fraunhofer-Gesellschaft established a unique support format in the German science funding landscape. The direct cooperation between universities, research institutions and industry inside this collaborative infrastructure has created new, effective and targeted paths and mechanisms for scientific added value. By 2017, the Fraunhofer-Gesellschaft had founded 17 High-Performance Centers in 11 German states. At the centers, the partners jointly carry out application-oriented research into future-oriented topics with a regional profile. The High-Performance Centers have proved to offer an ideal basis for successful innovation ecosystems. Consequently, Fraunhofer is further developing them into a national structure for research transfer in Germany. This will sustain and increase the impact of R&D services on the founding and performance of technology-oriented companies and make a contribution

1

to creating more – and more future-proof – employment in Germany.

Secure Connected Systems

Opened in 2017, the new High-Performance Center Secure Connected Systems offers a platform for digitalization in the priority areas of mobility, production engineering and health. It provides an application-oriented platform with an interdisciplinary focus for cross-sector and cross-disciplinary systematic research and cooperation. Participating companies benefit from the connectivity and outstanding subject-matter expertise of the Technical University of Munich, the Bundeswehr University Munich, Fraunhofer Institutes and Research Institutions for Applied and Integrated Security AISEC, for Microsystems and Solid State Technologies EMFT and for Embedded Systems and Communication Technologies ESK, and of the associated industrial partners. To expand the partner network, the center is open for collaborations with further research institutions. The High-Performance Center is supported and funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology, the Fraunhofer-Gesellschaft e. V. and industrial partners who engage in joint projects.

Integration of Biological and Physical-Chemical Material Functions

The High-Performance Center in Potsdam-Golm brings together the local Fraunhofer Institute for Applied Polymer Research IAP and the Department of Bioanalytics and Bioprocesses at the Fraunhofer Institute for Cell Therapy and Immunology IZI. In addition, the consortium comprises the University of Potsdam in an anchoring role, the Brandenburg University of Technology Cottbus-Senftenberg, the Institute of Biomaterial Science at the Helmholtz Zentrum Geesthacht, and the Max Planck Institute of Colloids and Interfaces. Under the banner of sustainability and efficiency, the priority research goal of the High-Performance Center resides in linking together various structural and functional characteristics of new materials and composites. To do this, the processing techniques and manufacturing technology are taken directly into account when developing the materials. The activities are primarily situated in the context of Industrie 4.0 and range from structurally integrated sensor systems in composites for lightweight design, to functional integration in fibers, textiles and smart card technologies for the security industry, to medical applications with lab-on-a-chip modules and implants with biofunctional surfaces.

Smart Production 1

In September 2017, the High-Performance Center Smart Production was opened in Chemnitz. The focus of this collaboration is the development of efficient value chains for function-optimized products through material and process innovations. Members of the consortium are the Fraunhofer Institutes for Machine Tools and Forming Technology IWU and for Electronic Nano Systems ENAS, Chemnitz University of Technology and local industry. At the center, research organizations in the fields of production, materials and lightweight design research work together on an interdisciplinary basis to develop new technologies on the subject of digitalization in manufacturing. Areas for action include 3D manufacturing technologies for functional integration, self-adapting autonomous systems and product-oriented auto-configuration of production chains.

2

Translational Biomedical Engineering 2

The infrastructure of the High-Performance Center Translational Biomedical Engineering in Hannover offers a platform for the transfer of medical developments from basic research into the sphere of clinical application and commercial exploitation. Its partners combine decisive expertise in the development of testing methods and compliance-based manufacturing and quality controls and in the field of risk analysis with safety and functional testing in accordance with the corresponding ISO standards. With a special emphasis on system definitions and studies for verification and validation, the High-Performance Center is strategically positioning itself in critical development processes for the successful commercial utilization of medical engineering. Situated in one of the most prominent national hubs of medical research, the core of High-Performance Center in Hannover is formed around the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM together with the Fraunhofer Institute for Reliability and Microintegration IZM and the Fraunhofer Institute for Surface Engineering and Thin Films IST. Broad participation by regional universities characterizes the make-up of the High-Performance Center, with the involvement of Hannover Medical School, Leibniz University Hannover, the University of Veterinary Medicine Hannover and Braunschweig University of Technology, and also of non-university partners in the shape of the Lower Saxony Centre for Biomedical Engineering and Laser Zentrum Hannover (LZH).

Weizenbaum Institute for the Networked Society
Self-determination in a digitalized world

With the establishment of the German Internet Institute, the German Federal Ministry of Education and Research is promoting cross-sectoral, interdisciplinary research into the Internet and digitalization. Its goal is to generate inspiring new ideas for the research landscape and create a scientific foundation for the debates in society at large and for political decision-making. The institute is named after the Internet pioneer, founding father of computer science and cultural critic, Joseph Weizenbaum.

As a member of the Founding Board, Professor for Quality Engineering of Open Distributed Systems at the Technical University of Berlin, and Director of the Fraunhofer Institute for Open Communication Systems FOKUS, Prof. Ina Schieferdecker ensures that the requisite technical expertise is at hand.

At the Weizenbaum Institute for the Networked Society, some 120 scientists will carry out research into the social changes associated with advancing technologization. Social scientists, economists and legal specialists work closely together with experts from the fields of design research and IT. At the core is the question as to how self-determination can be ensured in a networked society. The institute focuses on six major topics: work and innovation; contracts and responsibility in digital markets; governance and the setting of norms; technological change; digital education; and participation and the public sphere.

Fraunhofer "futureAM" focus project

Next-generationadditive manufacturing

With futureAM, Fraunofer is systematically driving forward the further development of additive manufacturing for metal components. To this end, six institutes have entered into a strategic project partnership: the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM, for Computer Graphics Research IGD, for Laser Technology ILT, for Material and Beam Technology IWS, for Machine Tools and Forming Technology IWU, and the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT.

The partners want to build up a comprehensive cooperation platform for highly integrated collaboration, drawing on Fraunhofer's decentralized, distributed resources in the area of additive manufacturing (AM). In addition, they want to create the technological conditions for a practice-relevant increase in the scalability, productivity and quality of AM processes for the manufacture of individualized metal components.

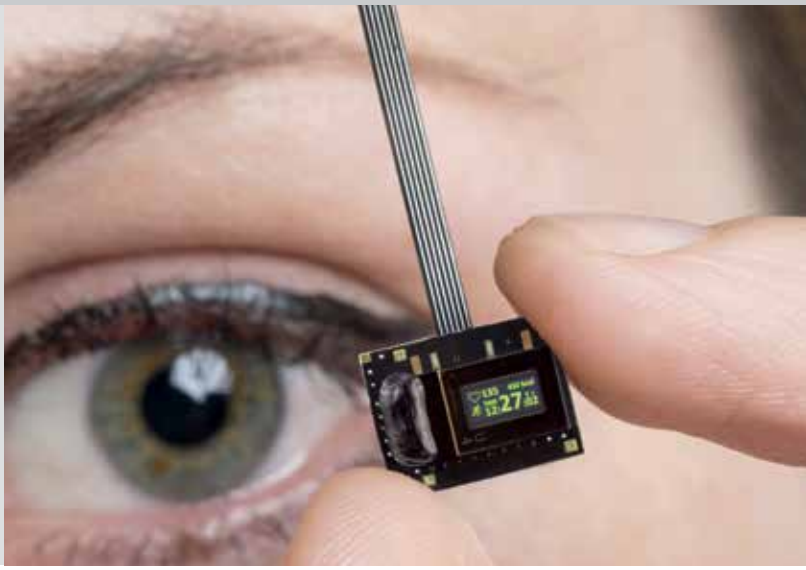
The goal for futureAM is to secure and further develop Fraunhofer's technological leadership in the field of additive manufacturing. Each institute coordinates one of four defined areas for action:

- Industrie 4.0 and digital process chains
- Scalable and robust AM processes
- Materials
- Systems technology and automation.

Project goals in the four action areas include a new type of software for automated AM component identification and optimization; a scalable SLM system concept with productivity increases of greater than a factor of 10; a method and a system technology for generating spatially resolved, customized multi-material characteristics; and an autonomous manufacturing cell for reworking AM components. The cooperation platform is created through intensive collaboration between the individual action areas, particularly through the establishment of a "virtual lab," where technology demonstrators will be developed.

AWARDS 2017

Alongside numerous prizes for first-class research, Fraunhofer researchers were also honored with some particularly prominent national and international awards for advances in applied research. We pay tribute to their achievement.



Franco-German Business Award

Innovative microdisplays

The Franco-German Business Award is bestowed biennially by the Franco-German chamber of industry and commerce, its aim being to further collaboration between French and German business by rewarding outstanding joint projects. In 2017, the award in the Innovation, New Technology and Industry 4.0 category went to partners MICROOLED and the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP in Dresden. MICROOLED was created in 2007 as a start-up spun off from CEA-LETI in France; since then it has become one of the world's leading providers of high-performance AMOLED microdisplays, featuring ultra-sharp and high definition images.

Fraunhofer FEP, meanwhile, has more than a decade of experience in the development of OLED microdisplays. This has proven the perfect soil for a fruitful partnership that began some time ago in the course of other joint EU-funded projects. In this particular joint project, Fraunhofer FEP is developing an innovative design for an integrated circuit for ultra-low-power OLED microdisplays, known as a backplane. On the basis of this backplane, MICROOLED has developed a complete OLED microdisplay module and together with Fraunhofer FEP they transferred the technology into production. Typical applications include devices such as data glasses or wearables. The microdisplay employs a new concept that requires extremely little power and is simpler to control. It is ideal for applications in which the entire system takes up little space, with a minimal integration environment and for applications which require just simple display functions – fitness trackers, for example.

Primetime Engineering Emmy Award

Efficient broadcasting of UHD video

The Primetime Emmy Engineering Award is bestowed in recognition of an engineering development that significantly improves on an existing technique, or else yields innovation that has a significant impact on TV broadcasting, recording or reception. At a ceremony held on October 25, 2017, this prestigious international prize was awarded to the Joint Collaborative Team on Video Coding (JCT-VC), which consists of the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, Huawei, MediaTek, Nokia, Qualcomm Incorporated, Samsung and the Sony Corporation.

The members of the team have been instrumental in shaping the HEVC standard, a codec that makes it extremely efficient to store and broadcast video in ultra high definition (UHD). The new HEVC standard is used in almost every UHD TV broadcasting medium, including antenna, satellite, cable, optical fiber and wireless TV. It is also supported by virtually all UHD-ready devices, including TVs, tablets and cellphones. HEVC offers a unique balance of extreme compression, HDR processing capacity, low complexity and minimum power consumption, making it an indispensable tool for a wide range of related products.

EARTO European Innovation Award

Reducing the cost of leather tanning

Leather is a popular and high-quality material, yet its production is not without its environmental problems. Usually, chrome salt is used as the tanning agent in the leather tanning process. Up to 40 percent of these salts end up in the wastewater, and recycling it is both technically complex and cost-intensive. As a result, the leather manufacturing industry is under increasing pressure to reduce emissions from the tanning process. Now, the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT has developed a new technique that helps solve the chrome salt environmental problem. Other advantages of the innovative CLEANTAN® technique include an up to 60 percent reduction in the sulphate load in the wastewater, a fivefold improvement in the processing time and significant cost savings. This means that the new technology provides a return on investment in under two years. Because of its cost benefits and environmental advantages, there is huge potential for applying the tanning technique both within the EU and internationally.

Dr. Manfred Renner of Fraunhofer UMSICHT was honored for his development of this technique in an awards ceremony in Brussels on October 11, 2017 at which he was presented with the Innovation Award from the European Association of Research and Technology Organisations (EARTO). EARTO is a non-profit international association. Its innovation award recognizes products and services that promise to deliver significant social or economic benefits for the EU.

PEOPLE IN RESEARCH

Enthusiasm and expertise are the lifeblood of our success. Here we spotlight six researchers as a representation of the many others who are doing top-rate work and delivering first-class results.

DR. HABIL. MARIO TRAPP

Engineer and computer scientist | Head of the ENARIS® Think Lab and acting managing director of the Fraunhofer Institute for Embedded Systems and Communication Technologies ESK in Munich

Design can become a passion – especially when a natural gift is coupled with career success. Often, the inclination is first observed in a person's choice of a creative environment. For Mario Trapp, that meant studying a particular mix of computer science and electrical engineering – and getting away from the rigid prescriptions of a specific field. His studies encouraged him to get to grips with the different ways in which engineers and computer scientists think. The nature of the work in this new field of study often called for improvisation – and a willingness to get hands on in terms of design. In fact, it is this early experience with hands-on design that Trapp sees as the basis of his career with Fraunhofer. His diploma thesis garnered early attention, his work honored as an outstanding achievement by the Friends of the University of Kaiserslautern. This was followed up by a doctorate undertaken in close collaboration with Robert Bosch GmbH; the fruits of his labor would go straight into its electronic stability program (ESP). This was a rich source of new experiences and new successes, since work on the industry scale follows its own rules and presents its own challenges. Today, Trapp has the satisfaction of knowing that the results of his work have been incorporated into millions of cars, helping to keep people safe on the road. As his enthusiasm for development and design continued to blossom, he was soon tasked with forming new organizational structures.

Having completed his highly praised doctoral thesis, in 2006 Trapp began building up a new department at the Fraunhofer Institute for Experimental Software Engineering IESE. This was a huge success, and he was rewarded by institute director Prof. Peter Liggesmeyer with the leadership of his own division department. Trapp completed his post-doctoral lecturing qualification in 2016, and in 2017 he took over as head of the ENARIS® Think Lab, which involves both Fraunhofer IESE and the Fraunhofer Institute for Embedded Systems and Communication Technologies ESK in Munich.

Evidently, the relationship between Trapp and Fraunhofer has been marked by mutual respect on both sides. As the research manager puts it: "Fraunhofer offers a unique blend of application and research. You can realize your projects, and you have an unmatched opportunity to be creative. Here, if you have a good idea, you can always find a way to implement it." As he takes on responsibility for others, he sees a chance to take the positive experience he has had with the people who encouraged him and to pass it on to his own employees.

It is little wonder that the father of two also likes tinkering and designing outside of work. In his free time, Trapp is a keen carpenter, and his family home on the edge of the forest near Kaiserslautern is now largely furnished with furniture he made in his own workshop.

JELENA OCHS M. SC.

Technical biologist | Head of the Life Sciences Engineering business unit at the Fraunhofer Institute for Production Technology IPT in Aachen

Life sciences engineering is a dynamic field that calls for a great deal of teamwork. Its purpose is to utilize insights from the life sciences and apply them in a technical environment. Expert teams of engineers, biologists and medics work hand in hand to develop tailored concepts and solutions to technical problems by applying engineering principles in a life sciences context. In this process, it is vital to consider the entire process chain and the way in which production processes are interconnected. This is the exciting and demanding field in which Jelena Ochs works on a daily basis. From here, she can drive developments and is always learning something new. This is something she really loves and was a motivating factor even back when she was choosing her course of study. By opting for technical biology for her master's degree, she found her way into a diverse and interdisciplinary discipline – one that not only offers an interface to industrial, medical, and plant biotechnology, but also maintains a connection with engineering. This makes it the ideal environment in which to put good ideas into action.

While still a student, Ochs was able to build on both her professional expertise and her language skills during a period abroad in Denmark. She completed her master's thesis at Sartorius Stedim Biotech in Göttingen, thus bringing her master's studies to a highly successful close. In 2016, while looking for a position in which to complete her doctorate, she came upon the Fraunhofer Institute for Production Technology IPT in Aachen, heralding the beginning of her career as a researcher working in laboratory automation. The following year, Ochs was among the women chosen to receive Fraunhofer's TALENTA *speed up* support.

The young, dynamic environment at Fraunhofer IPT is the ideal place from which to conduct her research – and for her personal development. The young researcher already heads up her own business unit in Life Science Engineering, working at the interface between engineering and the life sciences. Ochs sees her team as a highly motivated and productive community: "We have a unique chance to shape the medicine of the future, and that really spurs us on!" Together, the team develops new technology solutions for the automation of time- and cost-intensive processes in stem cell research.

Still, it's not just in the lab that Ochs is constantly striving for improvement. The responsibilities of her role also include launching new initiatives, encouraging exchange between the specialist departments and ultimately using the institute's resources to the best possible effect. Here, lighthouse projects with Fraunhofer CMI in Boston lend her work an international dimension. She also visits trade fairs and is involved in networking with representatives from other research institutions and industry.

All of these roles demand spontaneity, imagination and assertive communication. Luckily, Ochs is one of those people who makes a great public impression. Away from work, she is also a keen actress and likes to get involved in improvisational theater. Here, she can put her talents to use, just as she does in leading and spearheading her business unit. We have no doubt that there are some glittering performances ahead, both in and outside of work.


GOLLER

People in research

DR.-ING. ILJA RADUSCH

Computer scientist | Head of the Smart Mobility business unit at the Fraunhofer Institute for Open Communication Systems FOKUS, Head of the Daimler Center for Automotive Information Technology Innovations (DCAITI) at the Technische Universität Berlin

An end to all traffic jams – that's the big dream associated with automated driving. Not only should it make transportation more efficient, the hope is that it will make it safer and more convenient, too. Ilja Radusch heads up the business unit for Smart Mobility at the Fraunhofer Institute for Open Communication Systems FOKUS, and it is his mission to improve people's lives by optimizing mobility.

Born in East Berlin, Radusch has been fascinated with computers and mathematics since an early age. Back in the third grade, for instance, he won first place in the Maths Olympiad. With this passion for numbers, technology and tinkering, it was natural that he should go on to study computer science at the Technische Universität Berlin. Alongside his studies, he also worked for an agency that designed and organized trade fair appearances for a wide range of companies. "It was a great opportunity to learn how to present complicated technical solutions in a clear and comprehensible way," says Radusch – a skill that serves him to this day in his contact with customers, politicians and the media.

Radusch joined Fraunhofer FOKUS straight from university and has now worked there for fifteen years. He is a proud Berliner, and delighted that he didn't have to leave his home city to find a job. "Berlin is a young and dynamic place. You couldn't find the same range of students and start-ups anywhere else in Germany." These days, his mission is to get self-driving cars on the road as quickly as possible. "I like that my work at Fraunhofer is really application-focused, and the feeling I get that I'm directly shaping the future with my work." The computer scientist's work involves developing virtual test programs for automated vehicles, which save the time and expense of conducting tests using real automated vehicles.

One of the big challenges of automated driving is how to assemble the information from the various sensors, which are busy gathering information on obstacles and the distance and speed of other road users, into a complete picture. After all, the computer requires the whole picture if it is to accurately assess the traffic situation and make the right decisions. "When you realize the technical complexity behind the concept of automated driving, you're left full of admiration for the people who drive themselves safely from A to B," says Radusch. Even so, human drivers don't always stick hundred percent to the rules of the road – which poses yet another problem for automated cars. This is because, in the first instance, automated vehicles will have to share the road with their human counterparts. Accordingly, the focus of Radusch and his team is directed toward the ambitious goal of regulating this transitional phase and finding ways to improve mobility for all road users. He was recently involved in an important step in this direction when he coordinated the EU-funded TEAM research project on tomorrow's elastic adaptive mobility. TEAM combines vehicle electronics, mobile devices, navigation systems, tablets and smartphones into one big network, and uses the available data to provide road users with real-time traffic recommendations optimized for the entire city. This has real advantages both for road users and for the environment. The project was given the top "Excellent" rating by the European Commission.

PROF. DR. LILIANA FERREIRA

Mathematician | Engineer for electronics, telecommunications and information technology; director of Fraunhofer Portugal AICOS, professor at the University of Porto's Faculty of Engineering

Life begins with communication – as anyone who has ever had the privilege of witnessing the birth of a child can confirm. And communication remains essential throughout our lives. Hence the need to ensure that modern communication media are open and accessible to all members of society. This is the motivation that drives Liliana Ferreira's professional ambitions. First and foremost, we must understand exactly how communication works – how information is produced, conveyed, absorbed and processed. We also need to be practiced in today's communication technologies in order to further develop them in a useful way. This of course also applies to communication between humans and computers, which is rapidly gaining in significance.

Liliana Ferreira began her academic training in 1998 at the University of Porto studying for a degree in technical mathematics. After gaining her Licenciatura – comparable with a master's degree – she moved to Aveiro in 2002 and dedicated her further research to the same topics that still interest her most today: natural language processing and the use of artificial intelligence for clinical and health knowledge representation, information extraction, and high-performance, reliable human-machine communication. Her academic work culminated in a master's degree in electronics and telecommunications at the University of Aveiro and a doctoral thesis on computer-aided processing of medical language for which she was awarded a distinction.

As part of her research work, Liliana Ferreira spent time as a guest scientist working at IBM Research and Development in Böblingen in southwestern Germany. Here she was involved in developing a system that can speak written text in Portuguese. These kinds of language processors are not only employed in modern smart-home devices but can also be used in service robots, in museums and at events as well as in medicine and nursing.

Ferreira hopes above all that her research can benefit medicine: "I would like to make helpful communication systems that have been inaccessible until now available especially to people like doctors, nurses and carers." In March 2011 she discovered the right environment to achieve this at the Fraunhofer Research Center for Assistive Information and Communication Solutions AICOS in Porto. After a period spent conducting research at Philips Research in Eindhoven, the Netherlands, she took over the helm of AICOS in September 2017. She also holds a professorship in information technology at the University of Porto's Faculty of Engineering. In her development work, she uses COLABORAR, a network of senior co-designers. The highly motivated Fraunhofer research group bases a large part of its work on the experience and needs of senior citizens.

Liliana Ferreira also frequently finds inspiration in her own family's language abilities. With parents of mixed nationality who have worked in many different countries, it's no surprise that the two children are at home in four different languages: German, Portuguese, English and Dutch. The next generation of the multilingual Ferreira family is therefore following hard in their parents' footsteps.

PROF. DR. RER. NAT. HANS-MARTIN HENNING

Physics graduate | Managing director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Professor for Solar Energy Systems at the University of Freiburg's Institute for Sustainable Systems Engineering, Spokesman for the Fraunhofer Energy Alliance

Anyone who grew up in the 1970s no doubt remembers the energy controversies of the time, including oil crises, the warnings from the Club of Rome, and lively public debate about the finite nature of our resources to name just a few. Ever since, energy has been a topic that stayed with Hans-Martin Henning, director of the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg since 2017.

Fresh from school, he heard about a new department being set up at the University of Oldenburg focusing on the physics of renewable energy sources – and he was immediately hooked. At the beginning of the 1980s, he was one of the first physicists in the whole of Germany to focus on the topic of renewable energy in his undergraduate studies and doctoral thesis. Having obtained his PhD, Henning was brought to Fraunhofer ISE in Freiburg by his PhD supervisor. There he continued to pursue the topic that had formed the focus of his doctoral thesis: the development of efficient solar thermal cooling processes. Over the next years, Henning made a global name for himself as "Mr. Solar Cooling," a committed researcher who coordinated big international projects, including for the International Energy Agency (IEA) and on behalf of the European Union. Today, he also holds a chair at the University of Freiburg.

One of Henning's current research interests is numerical simulation, and at Fraunhofer ISE he has developed a mathematics- and physics-based calculation and optimization model for the entire energy system. The model takes into account development paths and interactions across all energy sources and end-use sectors. This makes it possible to calculate not only how to effect energy change most efficiently, but also where there is room for maneuver. For instance, one project currently underway on behalf of the German Federal Ministry of Transport and Digital Infrastructure (BMVI) is developing a climate protection scenario for the transportation sector within the context of the entire energy system based on renewable energies.

Thanks to the passionate physicist's hard work, Fraunhofer ISE is also first on the list in Europe when it comes to heat pumps. This technology extracts low-level temperature from the environment and converts it into useful heat using electrical energy or natural gas. The technique is extremely efficient, making it an important and sustainable component of heat provision to households and industry in the future in combination with renewables. As spokesman for the Fraunhofer Energy Alliance, Henning has made it his goal to make further progress on pooling the outstanding expertise of the Fraunhofer Institutes, thereby putting Fraunhofer on the map as the number one go-to for applied energy research.

These are ambitious goals, calling for extraordinary dedication. When asked what motivates him, the father-of-two says: "I passionately believe that we must all do our bit to limit the effects of man-made climate change. It's the only way to avoid dramatic changes in the natural systems that regulate our climate and the impact this will have on humanity. I'm convinced that technology targeting renewables and energy efficiency has a critical role to play."

People in research

MELANIE GRALOW M. SC.

Mechanical engineer | Head of the Bionic Function & Design group at the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT in Hamburg

Being open to new ideas is a great motto for anyone looking to prepare themselves for the work of the future, in which creativity and lifelong learning are called for as never before. Ironically "new" can actually be something very old that we didn't really look at before. Biomimetics for instance, is a whole discipline that revolves around the designs found in nature – designs based on millions of years of evolution. The really fascinating thing is that it is only today – using ultramodern technology – that we are able to reproduce some of these "ancient" structures at all.

With her wide-ranging education, career path and international experience, Melanie Gralow is the ideal candidate to make the most of this exciting interface between evolutionary research and state-of-the-art high-tech manufacturing. After leaving school, the young researcher quickly expanded her horizons with a year spent abroad in the U.S., studies in biomimetics in Bremen, a semester spent studying abroad in Australia and numerous other travels around the globe. Constantly moving from one place to another, Gralow has cultivated a great openness for new roles and new topics – laying the foundation for her success.

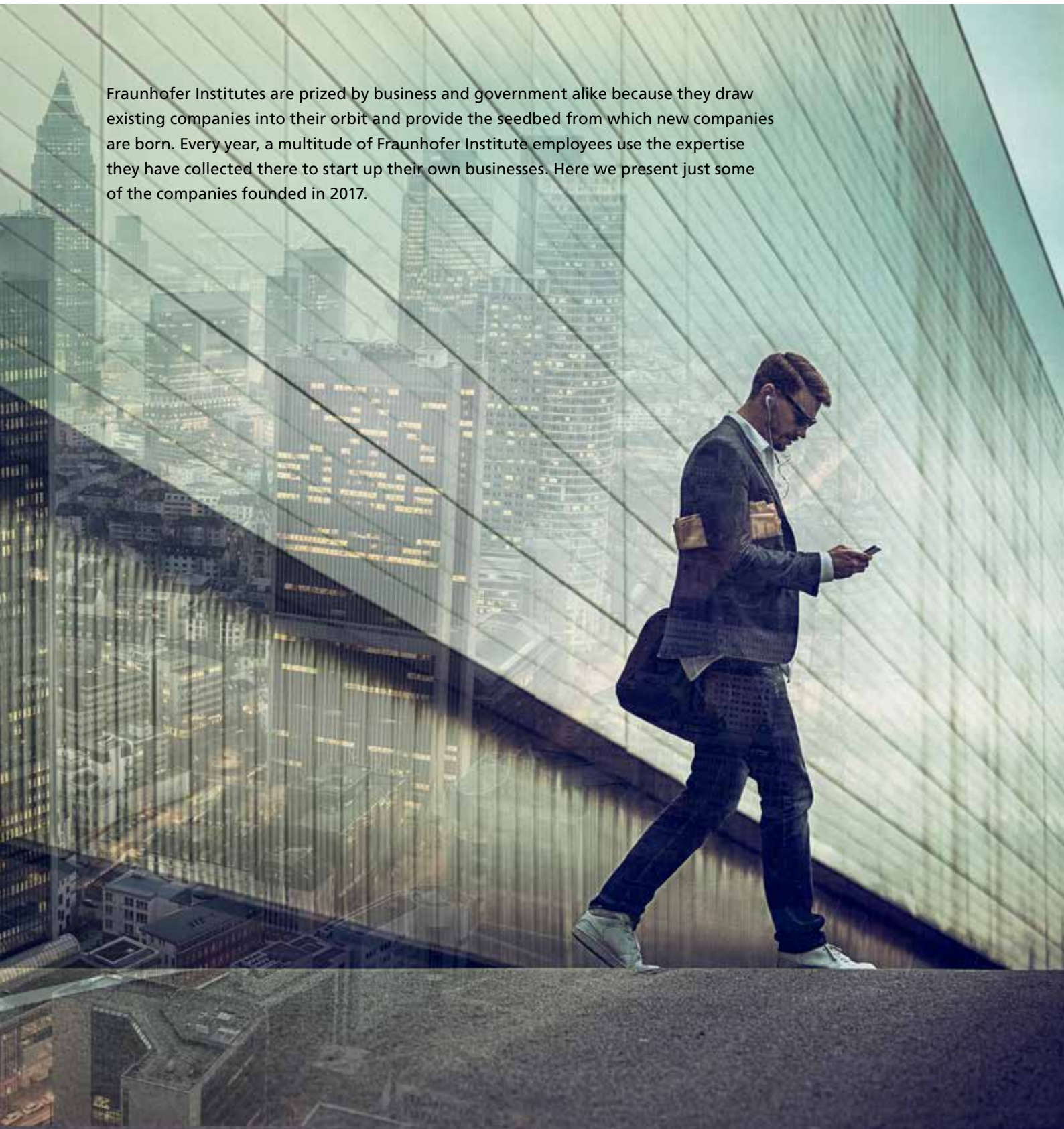
Her first contact with Fraunhofer was in 2013, when she became a student assistant at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen. It was here that she teamed up with four other students in additive manufacturing to embark on a master's project entitled "Cooling with Heat." In this project, the ambitious team set out to show that you can use heat for cooling purposes by drawing on a thermoelectric generator that uses the temperature difference to generate current that subsequently drives a ventilation system. Additive manufacturing was used to produce essential components for the self-regulating system. It took a year to get from the idea to a functioning prototype, which was when the international accolades began pouring in: First prize from Stratasys, world leader in 3D printing from the U.S., first prize from Additive Industries, a newcomer from the Netherlands, and first prize from Rapid.Tech, the international trade fair for additive technologies in Erfurt.

These are great accomplishments for someone who was still a student. Having completed her master's thesis on the use of biomimetic design in additive manufacturing at what is now Fraunhofer IGCV in Augsburg, Gralow entered the world of work. When a job came up that fit her talents perfectly, she didn't have to think twice: LZN Laser Zentrum Nord in Hamburg was looking for a researcher to work on the EU-sponsored Bionic Aircraft project, with experience in additive manufacturing, bionics, design, sustainability and international collaboration.

Gralow took up the position in December 2016 – expanded to include leadership of the Bionic Function & Design research group in May 2017. However, her time with Fraunhofer was only briefly interrupted, since at the beginning of 2018 LZN Laser Zentrum Nord was integrated into the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT. This is a great triumph for Fraunhofer since, as the example of Melanie Gralow goes to show, the expertise and skills assembled in the LZN Laser Zentrum Nord are ideally suited to forward-looking applied research.

FRAUNHOFER INSTITUTE SPIN-OFFS

Fraunhofer Institutes are prized by business and government alike because they draw existing companies into their orbit and provide the seedbed from which new companies are born. Every year, a multitude of Fraunhofer Institute employees use the expertise they have collected there to start up their own businesses. Here we present just some of the companies founded in 2017.



SpinPlant GmbH

An innovative collagen membrane for regenerative medicine

Diabetics often suffer from wounds that refuse to heal. An innovative collagen membrane developed by SpinPlant GmbH could help to speed along the healing process. Moreover, the membrane can also be used for many other purposes, including bone filling material, bone regeneration, dental medicine and tissue replacement. Collagen is one of the basic building blocks of the human body, found in bone and skin cells in particular. So when doctors insert a collagen membrane into the body or on top of a wound, the patient's body accepts it as its own. The collagen also inhibits inflammation and stimulates the body to produce its own organic tissue. The best thing about the new collagen membrane, though, is its hair-thin woven fibers that create tiny pores at the micrometer and nanometer level. These pores allow cells to grow through the membrane, adhere to the nanofibers for support, clump and divide. The collagen remains structurally intact even after the production of the nano- and micro-porous membranes. It is biologically active and, thanks to their specific wetting properties, the nanofibers remain stable within the human body. The membrane is also cheaper to produce than standard collagen products.

SpinPlant produces the membranes at the Fraunhofer Institute for Microstructure of Materials and Systems IMWS. The company intends to enter the marketplace both as an OEM supplier and as a manufacturer of finished products. It will shortly obtain medical device certification according to ISO 13485, with end-product approval in Europe and the U.S. to follow. The supplier products are intended for use in bone filling and bone regeneration, the healing of wounds, tissue engineering and cell therapy. The first end product is a bone filling material.

spinplant

mHealth Pioneers GmbH

Digital infrastructure for health apps

You haven't heard anything from your grandma for two days – is she alright? Is your Dad getting enough exercise after his heart operation? And what about your own sleep? These are all familiar questions to families, health service providers and researchers – and answering them has always cost a lot of time and effort. Now, everyone can sit back and let the "Thryve" platform of mHealth Pioneers GmbH do the work. The company offers access to all currently available fitness trackers, coupled with precise algorithms to fuse sensor data and automatically record health data on standard Smartwatches. This automated generation and interpretation of diverse data relieves both patients and health care services.

The company is also accelerating the development of entire new health services by offering a comprehensive care infrastructure as a white label solution. This allows client companies to operate the Thryve services under their own brand. The system complies with all relevant regulations and is certified with regard to medical product regulation and data protection. mHealth Pioneers GmbH is a spin-off of the Fraunhofer Institute for Computer Graphics Research IGD, founded in October 2016 as part of the EXIST research transfer program. One year later, it had doubled its number of employees, serving customers from both research and the care sector as well as the digital health industry.

Thryve

Elosun GmbH

New sunflower proteins for tasty veggie foods

On average, it takes seven kilograms of plant mass to produce the equivalent of one kilogram of animal protein – meat, sausage or milk, for instance. In the long term, we need to rethink our approach to food production, in the light of the planet's steadily growing population. The hope is that products made from soybeans, lupines, almonds and the like could replace animal products, providing more sustainability in the food supply. However, most of these products have a peculiar taste that takes a lot of getting used to. Sunflower proteins are different because they actually taste good. There is no genetic modification involved, nor do they contain any allergens. The proteins are ideal for producing vegetarian or vegan foods such as meat substitutes, baked goods, spreads, milk chocolate and milk substitutes. Mayonnaise is the perfect example. The egg yolk traditionally used as an emulsifier to bind the fat and water could be replaced with sunflower protein.

Elosun GmbH was founded in April 2017 as a spin-off of the Fraunhofer Institute for Process Engineering and Packaging IVV, for the purpose of commercializing the new functional sunflower protein. The company plans to manufacture the proteins in a purpose-built factory and market them worldwide. Currently, Elosun is looking for investors to help finance the production facility. The aim is to be able to start production in early 2019, followed by commercialization of the new product.

Virtual Fort Knox AG

Cooperative service platform helps small and medium-sized businesses access Industrie 4.0

Industrie 4.0 promises to connect production machinery and tools, bringing increased efficiency to production processes. Even so, small and medium-sized businesses often struggle to apply this approach to their daily operations. The main problem is the infrastructure required to implement the desired connectivity, seeing as the platform solutions offered by the big players are extremely expensive. In addition, if companies do decide to go with a solution from one particular provider, they are tied in for the long term. There are only limited possibilities to integrate solutions from other providers with these sorts of platform – if it is possible at all. This prompts some small and medium-sized businesses to build their own platforms – an extremely expensive and time-consuming undertaking that not all of them can afford. Virtual Fort Knox AG, a spin-off of the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, offers a solution to the problem in the form of an independent, open service delivery platform that can be used by customers ranging from software companies to machine-tool manufacturers to host their solutions and offerings. In turn, the SME end users benefit from a fully protected data space in which their data is stored securely and within which they can put together the solution that suits their business the best.

SUNBLOOM PROTEINS

Virtual Fort Knox AG was founded in 2015. A pilot version of the platform is already up and running in the institutes of the Fraunhofer Group for Production so that interested companies can test it out at institutes spread across Germany. Currently, Virtual Fort Knox is looking for five to six investors – with the desire that the ownership structure should remain evenly distributed and reflect the cooperative nature of the platform. The commercial version of the platform is expected to be ready by the fall of 2018.

Enerthing GmbH

Powering small devices with photovoltaic energy

These days, it can be hard to keep track of things in the busy world of a big hospital. Has my patient's bed been moved to another unit? In which ward can I find that mobile device I need? To help in these sorts of situation, more and more objects are being fitted with small transmitters known as beacons. In other sectors, too, the Internet of Things means that billions of electronic components, sensors and other small devices are being connected with one another, as in the domain of logistics. Currently, almost all of these devices are powered by disposable batteries. These have to be replaced every two years or so – and can easily cost up to 100 euros per beacon.

What Enerthing GmbH offers is a more economical – and more ecological – alternative. The idea is to replace disposable batteries with malleable photovoltaic foils to power the devices. The foils don't need more than the few hundred lux from interior lighting such as LED lamps – you could almost think of them as a successor to the solar cells on pocket calculators, but twice as efficient. Instead of having to replace the batteries every two years, it is enough to service the beacons once every eight years. An innovative production concept has made it possible to produce the photovoltaic modules quickly and cost effectively in a roll-to-roll process.

Enerthing GmbH was founded in 2016, and currently employs six people. Its investors include the Fraunhofer-Gesellschaft and NRW.BANK. By mid-2018, the employees expect to be able to produce small batches of ten to one hundred customer modules using their laboratory facility. At the same time, they are working with various industry partners to scale up the production processes, and bigger quantities should be available in 2019.

Virtual Fort Knox

Enerthing
Solar Energy Solutions for Things

FINANCIAL REPORT

BALANCE SHEET AT DECEMBER 31, 2017

FRAUNHOFER-GESELLSCHAFT
ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E. V., MÜNCHEN

ASSETS	€	€	**2017** €	**2016** € (1000)
Current assets				
Cash and cash equivalents		184,549,086.55		83,586
Marketable securities		337,942,451.90		298,872
Accounts receivable and other current assets				
Trade receivables	237,075,119.56			240,190
Receivables from the federal and state governments				
relating to base funding	27,275,768.37			35,568
relating to project billing, including contract research	157,966,686.64			118,199
relating to pension and compensated absence provisions	66,017,700.00			62,379
	251,260,155.01			216,146
Accounts receivable from associated companies	11,738,450.15			13,452
Other current assets	135,428,439.36			122,235
		635,502,164.08		592,023
Inventories		34,742,006.84		31,357
Prepaid expenses and deferred charges		12,632,907.01		14,786
Total current assets			1,205,368,616.38	1,020,624
Intangible assets			27,080,800.64	10,610
Property, plant and equipment			1,932,593,451.89	1,898,300
Financial assets			21,164,376.74	22,125
Total assets			**3,186,207,245.65**	**2,951,659**
Trust assets			27,120,041.33	58,969

LIABILITIES AND EQUITY	€	€	2017 €	2016 € (1000)
Current liabilities				
Trade payables		103,514,291.37		84,081
Unappropriated grants from the federal and state governments				
relating to base funding	210,845,378.36			119,105
relating to project billing	63,777,671.12			36,032
		274,623,049.48		155,137
Accounts payable to associated companies		343,556.87		–
Other current liabilities		9,560,046.50		11,299
Total current liabilities			388,040,944.22	250,517
Deferred income			86,145.17	4,236
Provisions for pensions and similar obligations			9,287,700.00	9,379
Other provisions			148,030,150.00	143,261
Special reserves				
License-fee revenue reserve		338,908,285.76		298,908
Grants relating to non-current assets		1,964,583,357.11		1,914,730
Grants used to finance current assets		247,555,110.08		236,056
Present value of deferred income from patent deal		73,260,967.01		78,051
			2,624,307,719.96	2,527,745
Equity				
Capital of the non-profit organization				
Carried forward	15,148,728.45			14,928
Retained earnings	84,082.36			221
		15,232,810.81		15,149
Restricted reserve		1,221,775.49		1,372
Total equity			16,454,586.30	16,521
Total liabilities and equity			**3,186,207,245.65**	**2,951,659**
Trust liabilities			27,120,041.33	58,969

INCOME STATEMENT FOR THE FINANCIAL YEAR 2017

FRAUNHOFER-GESELLSCHAFT
ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V., MÜNCHEN

			2017	2016
	€	€	€	€ (1000)
Revenue from base funding				
Federal government		604,266,494.60		583,593
State governments		97,806,983.72		87,992
			702,073,478.32	671,585
Revenue from own activities				
Revenue from research and development activities				
Federal government: Project funding	480,287,902.49			370,685
Contracts	9,446,542.44			9,902
State governments: Project funding	137,107,257.06			149,134
Contracts	1,430,662.68			2,183
Business, industry and trade associations	692,147,911.23			668,461
Research funding organizations and other sources	187,622,644.41			197,536
		1,508,042,920.31		1,397,901
Other revenue		9,831,022.02		15,071
Total revenue			1,517,873,942.33	1,412,972
Increase in work in progress		39,358,041.02		842
Other internally constructed and capitalized assets		7,340,709.32		7,258
Other operating income		28,666,443.75		17,749
Income from equity investments		1,727,640.01		12,956
Other interest and similar income		927,919.05		50
			78,020,753.15	38,855
Total base funding and revenue from own activities			2,297,968,173.80	2,123,412
Change in special reserves				
License-fee revenue reserve		−40,000,000.00		−40,700
Grants relating to non-current assets		−58,361,920.09		60,615
Grants used to finance current assets		−11,498,882.47		−41,577
			−109,860,802.56	−21,662
Total income available to cover expenditure			**2,188,107,371.24**	**2,101,750**

	€	€	2017 €	2016 € (1000)
Cost of materials		357,952,261.29		336,141
Personnel expenses		1,247,808,098.78		1,181,594
Amortization of intangible assets and depreciation of property, plant and equipment		285,722,611.58		287,193
Other operating expenses		294,234,690.62		294,595
Amortization of financial assets and current marketable securities		1,856,780.66		1,566
Interest and similar expenses		598,802.97		411
Total expenditure			2,188,173,245.90	2,101,500
Net income for the year			–65,874.66	250
Transfer from reserves			152,157.02	–
Transfer to reserves			–2,200.00	–29
Retained earnings			84,082.36	221
Allocation to capital of the non-profit organization			–84,082.36	–221
			–	–

RECONCILIATION BETWEEN INCOME STATEMENT AND PERFORMANCE STATEMENT (CASH-BASIS ACCOUNTING) 2017

Income/receipts	Performance statement	Non-profit organization capital	Reconciling items	Income statement
	€	€	€	€
Income/receipts				
from base funding	698,434,478.32		3,639,000.00	702,073,478.32
from research and development activities	1,549,269,642.47		−41,226,722.16	1,508,042,920.31
from other sources	385,785.98		9,445,236.04	9,831,022.02
Increase in work in progress			39,358,041.02	39,358,041.02
Other internally constructed and capitalized assets	7,340,709.32			7,340,709.32
Other income	38,559,161.40	339,396.31	−7,576,554.90	31,322,002.81
Total income/receipts	**2,293,989,777.49**			
Change in special reserves				
License-fee revenue reserve			−40,000,000.00	−40,000,000.00
Grants relating to non-current assets				
Allocations to special reserves (capital expenditure)			−345,789,110.48	−345,789,110.48
Reversal of special reserves (depreciation)		43,762.92	287,383,427.47	287,427,190.39
Grants used to finance current assets	−11,498,882.47			−11,498,882.47
Change in grants receivable relating to pension and compensated absence provisions	3,639,000.00		−3,639,000.00	
Total business volume (cash basis)	**2,286,129,895.02**			
		383,159.23	−98,405,683.01	2,188,107,371.24

Expenditure/disbursements	Performance statement	Non-profit organization capital	Reconciling items	Income statement
	€	€	€	€
Expenditure/disbursements				
Cost of materials	326,064,724.84	27,008.18	31,860,528.27	357,952,261.29
Personnel expenses	1,259,575,419.56	5,640.00	–11,772,960.78	1,247,808,098.78
Amortization of intangible assets and depreciation of property, plant and equipment		195,964.77	285,526,646.81	285,722,611.58
Other operating expenses	314,657,721.45	220,420.94	–18,187,868.14	296,690,274.25
Expenditure as per the income statement				**2,188,173,245.90**
Change in special reserves				
License-fee revenue reserve	40,000,000.00		–40,000,000.00	
Capital expenditure (current and major infrastructure)	345,832,029.17		–345,832,029.17	
Net income for the year		–65,874.66		–65,874.66
Total business volume (cash basis)	**2,286,129,895.02**	383,159.23	–98,405,683.01	2,188,107,371.24

PERFORMANCE STATEMENT FOR INDIVIDUAL FRAUNHOFER ENTITIES

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses	Capital expenditure	**Income** From external sources	Base funding
		2017 € (1000)	**2017** € (1000)	**2017** € (1000)	**2017** € (1000)
Fraunhofer ICT Group					
Algorithms and Scientific Computing SCAI	Sankt Augustin	10,346.4	693.3	8,559.3	2,480.4
Applied and Integrated Security AISEC	Garching b. München	8,402.3	454.1	7,343.3	1,513.1
Applied Information Technology FIT	Sankt Augustin	15,913.4	734.3	13,844.4	2,803.3
Communication, Information Processing and Ergonomics FKIE	Wachtberg	6,458.4	56.0	6,216.3	298.1
Computer Graphics Research IGD	Darmstadt, Rostock	17,411.7	635.0	11,061.8	6,984.9
Digital Media Technology IDMT	Ilmenau, Oldenburg	13,150.6	568.1	8,925.4	4,793.4
Embedded Systems and Communication Technologies ESK	München	5,170.2	238.1	3,751.4	1,656.9
Experimental Software Engineering IESE	Kaiserslautern	12,642.5	580.2	11,343.9	1,878.9
Industrial Mathematics ITWM	Kaiserslautern	24,607.4	1,141.1	18,643.5	7,105.0
Intelligent Analysis and Information Systems IAIS	Sankt Augustin	18,572.7	444.0	18,048.4	968.3
Medical Image Computing MEVIS	Bremen	8,567.1	499.9	5,052.0	4,015.0
Open Communication Systems FOKUS	Berlin	31,911.7	1,295.2	26,147.7	7,059.2
Optronics, System Technologies and Image Exploitation IOSB	Karlsruhe, Ettlingen, Ilmenau, Lemgo	33,973.4	3,317.5	25,063.9	12,226.9
Secure Information Technology SIT	Darmstadt	11,314.9	141.8	8,312.0	3,144.8
Software and Systems Engineering ISST	Dortmund	3,662.9	179.3	2,692.2	1,150.0
Transportation and Infrastructure Systems IVI	Dresden	9,536.6	949.1	9,016.1	1,469.6
		231,642.3	**11,927.1**	**184,021.6**	**59,547.8**

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses	Capital expenditure	**Income** From external sources	Base funding
		2017 € (1000)	**2017** € (1000)	**2017** € (1000)	**2017** € (1000)
Fraunhofer Group for Innovation Research – INNOVATION [1]					
Center for International Management and Knowledge Economy IMW	Leipzig	5,487.0	93.4	3,328.8	2,251.6
Industrial Engineering IAO	Stuttgart	31,298.6	3,135.0	27,069.9	7,363.7
Information Center for Planning and Building IRB	Stuttgart	7,033.5	110.8	2,552.6	4,591.7
Systems and Innovation Research ISI	Karlsruhe	23,901.7	213.4	20,225.7	3,889.4
Technological Trend Analysis INT	Euskirchen	2,726.0	41.6	2,237.3	530.3
		70,446.7	**3,594.2**	**55,414.3**	**18,626.6**
Fraunhofer Group for Life Sciences					
Biomedical Engineering IBMT	Sulzbach, St. Ingbert	15,697.4	1,107.3	12,397.7	4,407.0
Cell Therapy and Immunology IZI	Leipzig, Potsdam-Golm	32,720.7	1,941.5	25,583.8	9,078.4
Interfacial Engineering and Biotechnology IGB	Stuttgart, Leuna	24,509.5	2,290.8	16,458.5	10,341.8
Marine Biotechnology and Cell Technology EMB	Lübeck	2,931.0	60.3	1,977.4	1,013.9
Molecular Biology and Applied Ecology IME	Aachen, Schmallenberg	41,108.4	3,944.3	36,874.1	8,178.6
Process Engineering and Packaging IVV	Freising, Dresden	20,206.0	1,238.6	15,703.6	5,740.9
Toxicology and Experimental Medicine ITEM	Hannover, Braunschweig, Regensburg	28,492.3	1,921.0	19,536.5	10,876.7
		165,665.5	**12,503.6**	**128,531.7**	**49,637.4**

1 New Fraunhofer Group since 2017; including Fraunhofer IRB, official member of this Fraunhofer Group since January 1, 2018.

Performance statement for individual Fraunhofer entities

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses	Capital expenditure	**Income** From external sources	Base funding
		2017 € (1000)	**2017** € (1000)	**2017** € (1000)	**2017** € (1000)
Fraunhofer Group for Light & Surfaces					
Applied Optics and Precision Engineering IOF	Jena	29,267.7	5,635.6	24,572.0	10,331.3
Laser Technology ILT	Aachen	34,405.0	5,501.7	30,662.8	9,243.9
Material and Beam Technology IWS	Dresden	29,090.6	2,426.0	23,057.0	8,459.7
Organic Electronics, Electron Beam and Plasma Technology FEP	Dresden	24,734.2	1,090.2	19,657.1	6,167.3
Physical Measurement Techniques IPM	Freiburg	15,242.8	813.0	12,043.0	4,012.8
Surface Engineering and Thin Films IST	Braunschweig	11,654.5	693.3	8,595.5	3,752.2
		144,394.8	**16,159.8**	**118,587.3**	**41,967.3**
Fraunhofer Group for Microelectronics					
Applied Solid State Physics IAF	Freiburg	11,427.9	1,121.4	10,184.1	2,365.2
Electronic Nano Systems ENAS	Chemnitz	12,620.9	2,723.7	9,724.8	5,619.8
High Frequency Physics and Radar Techniques FHR	Wachtberg	16,459.2	1,156.1	14,518.0	3,097.3
Integrated Circuits IIS	Erlangen, Nürnberg, Dresden	168,336.0	18,112.3	167,494.5	18,953.8
Integrated Systems and Device Technology IISB	Erlangen	26,081.9	2,447.7	21,803.1	6,726.5
Microelectronic Circuits and Systems IMS	Duisburg	28,528.9	446.1	21,911.4	7,063.6
Microsystems and Solid State Technologies EMFT	München	13,746.8	435.9	9,534.4	4,648.2
Photonic Microsystems IPMS	Dresden	37,907.0	1,691.5	27,872.1	11,726.4
Reliability and Microintegration IZM	Berlin, Dresden	30,211.2	1,660.3	25,614.7	6,256.7
Silicon Technology ISIT	Itzehoe	24,919.9	613.0	19,581.1	5,951.8
Telecommunications, Heinrich-Hertz-Institut, HHI	Berlin, Goslar	47,736.0	5,774.0	41,113.4	12,396.6
		417,975.6	**36,182.0**	**369,351.7**	**84,805.8**

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses	Capital expenditure	**Income** From external sources	Base funding
		2017 € (1000)	**2017** € (1000)	**2017** € (1000)	**2017** € (1000)
Fraunhofer Group for Production					
Casting, Composite and Processing Technology IGCV	Augsburg, Garching b. München	11,150.5	1,288.2	10,675.3	1,763.4
Environmental, Safety and Forming Technology UMSICHT	Oberhausen, Sulzbach-Rosenberg	39,329.9	2,064.9	34,189.3	7,205.6
Factory Operation and Automation IFF	Magdeburg	20,186.4	735.2	16,586.7	4,334.8
Large Structures in Production Engineering IGP	Rostock	6,976.4	216.8	5,795.1	1,398.1
Machine Tools and Forming Technology IWU	Chemnitz	38,170.5	2,173.5	29,315.6	11,028.4
Manufacturing Engineering and Automation IPA	Stuttgart	59,231.6	3,820.2	48,423.1	14,628.8
Material Flow and Logistics IML	Dortmund, Hamburg	29,163.3	1,592.2	24,087.8	6,667.7
Mechatronic Systems Design IEM	Paderborn	9,257.9	313.7	8,301.3	1,270.3
Production Systems and Design Technology IPK	Berlin	18,400.8	1,497.3	15,865.5	4,032.7
Production Technology IPT	Aachen	27,912.5	2,887.7	22,248.6	8,551.7
		259,779.9	**16,589.8**	**215,488.2**	**60,881.4**
Fraunhofer Group for Defense and Security VVS [1]					
Applied Solid State Physics IAF	Freiburg	15,104.3	3,228.8	9,539.7	8,793.5
Chemical Technology ICT, Department of Energetic Materials	Pfinztal	13,494.9	1,504.0	4,438.6	10,560.3
Communication, Information Processing and Ergonomics FKIE	Wachtberg	24,426.6	1,841.3	13,539.5	12,728.4
High Frequency Physics and Radar Techniques FHR	Wachtberg	15,845.4	1,114.2	6,112.2	10,847.4
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	15,075.5	1,375.6	6,116.0	10,335.2
Optronics, System Technologies and Image Exploitation IOSB, Ettlingen branch	Ettlingen	17,691.5	1,759.5	13,177.5	6,273.5
Technological Trend Analysis INT	Euskirchen	6,586.4	1,472.9	3,437.6	4,621.7
		108,224.6	**12,296.4**	**56,361.0**	**64,160.0**

1 Not including contract research activities.

Performance statement for individual Fraunhofer entities

Fraunhofer Institute/ Research Institution for		**Expenses** Operating expenses	Capital expenditure	**Income** From external sources	Base funding
		2017 € (1000)	**2017** € (1000)	**2017** € (1000)	**2017** € (1000)
Fraunhofer Group for Materials and Components – MATERIALS					
Applied Polymer Research IAP	Potsdam-Golm	19,316.7	1,576.1	14,361.3	6,531.4
Building Physics IBP	Stuttgart, Holzkirchen	24,341.1	467.0	17,077.8	7,730.3
Ceramic Technologies and Systems IKTS	Dresden, Hermsdorf	52,381.7	3,132.0	42,048.1	13,465,6
Chemical Technology ICT, Polymer Engineering Department	Pfinztal, Karlsruhe	38,162.3	4,527.9	34,182.3	8,507.9
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	7,851.7	490.5	6,340.9	2,001.3
Manufacturing Technology and Advanced Materials IFAM	Bremen, Dresden, Stade	44,700.9	3,897.7	36,681.4	11,917.2
Mechanics of Materials IWM	Freiburg	20,288.9	1,619.3	15,051.8	6,856.3
Microstructure of Materials and Systems IMWS	Halle	20,377.7	2,252.5	16,732.9	5,897.4
Nondestructive Testing IZFP	Saarbrücken	14,019.3	1,578.0	8,637.4	6,959,9
Silicate Research ISC	Würzburg, Bronnbach, Garching b. München, Bayreuth	33,067.0	1,968.3	25,911.1	9,124.1
Solar Energy Systems ISE	Freiburg, Halle	76,414.6	13,950.1	83,275.3	7,089.4
Structural Durability and System Reliability LBF	Darmstadt	28,187.6	2,063.2	21,328.3	8,922.5
Wind Energy and Energy System Technology IWES	Bremerhaven, Kassel	41,484.9	17,585.0	53,490.9	5,579.0
Wood Research, Wilhelm-Klauditz-Institut, WKI	Braunschweig	16,049.1	1,857.2	13,442.6	4,463.7
		436,643.4	**56,964.9**	**388,562.3**	**105,046.0**
Centrally managed entities					
Fraunhofer headquarters	München	26,581.5	5,113.6	4,494.0	27,201.2
Institute Center Birlinghoven	Sankt Augustin	709.7	33.9	231.9	511.7
Institute Center Stuttgart	Stuttgart	–9.6	591.6	15,2	566.8
General overhead costs		78,243.5	451.1	1,446.8	77,247.8
Major infrastructure capital expenditure			173,424.1	73,049.2	100,374.8
		105,525.1	**179,614.4**	**79,237.2**	**205,902.3**
Performance Statement		**1,940,297.9**	**345,832.0**	**1,595,555.3**	**690,574.6**
Total Business Volume			**2,286,129.9**		

EXCERPTS FROM THE NOTES TO THE FINANCIAL STATEMENTS 2017

I. General disclosures

The Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., headquartered in Munich, is a non-profit organization registered with the district court of Munich under the reference code VR 4461.

The annual financial statements for the year ending December 31, 2017, were prepared voluntarily and in accordance with the requirements of the German Commercial Code (HGB) as applicable to large corporate entities. The income statement was prepared in accordance with the total cost method.

The basis of the Fraunhofer-Gesellschaft's accounting is the performance statement, from which the annual financial statements are derived.

The performance statement is adapted to the requirements of the public funding authorities in terms of format and reconciliation. It provides a breakdown of operating expenses and capital expenditure at three different levels: individual institutes, headquarters, and the organization as a whole. The components of the operating budget are presented as income or expenses in accordance with generally accepted accounting principles. Capital expenditure on property, plant and equipment and on financial assets, on the other hand, is recognized at cost on acquisition of the assets. Therefore the operating budget does not include any depreciation/amortization expenses on these items. In order to provide full accountability for grants received from funding agencies, the performance statement for the organization as a whole is reconciled to the income statement format required by public authorities by eliminating the effect of non-cash income and expense items. The amounts presented in the income statement include items showing the changes in payables and receivables and in depreciation/amortization charges compared with the previous year. On the face of the balance sheet, these reconciliation items are included in the special reserves for grants relating to fixed assets and for grants used to finance current assets. The figures from the performance statement are explained in the management report, where they are broken down into the areas of contract research, defense research and major infrastructure capital expenditure.

Annual financial statements of the Fraunhofer-Gesellschaft			Reconciliation with **income statement** format required by public funding authorities
Balance sheet	Income statement		
	Reconciliation between income statement and performance statement		
Management report	**Performance statement**		
	Budgeted operating expenses and capital expenditure at Fraunhofer-Gesellschaft level "total business volume (cash basis)"		
Notes to the financial statements	Separate financial statements of the institutes/headquarters		
	Operating budget	Capital expenditure	
	Costs (excluding depreciation and amortization)	Expenses	
	Income	Income	

Presentation of annual accounts of the Fraunhofer-Gesellschaft

II. Recognition and measurement methods

Intangible assets and property, plant and equipment are measured at amortized cost, i.e. the cost of acquisition or construction less depreciation/amortization calculated on a straight-line basis.

Intangible assets are amortized over a useful life of three years.

Institute buildings on own and third-party land are depreciated as follows:
- Added before April 1985: at 2 percent
- Added between April 1, 1985 and December 31, 2000: at 4 percent
- Added after January 1, 2001: at 3 percent

A useful life of five years is applied to movable items of property, plant and equipment. However, a useful life of four years is assumed for communication, video and audio systems and of three years for IT hardware. Motor vehicles are depreciated over a useful life of four years.

Financial assets are measured at cost or at fair value, whichever is lower.

Since the non-current assets presented in the ordinary accounts are financed by government grants, the special reserve for grants relating to non-current assets is reduced by an amount corresponding to the depreciation/amortization of these assets. Therefore, these adjustments have no impact on the income statement.

Work in progress is measured at the cost of construction or fair value, whichever is lower. Construction costs include applicable personnel expenses, cost of materials, general administrative expenses, and depreciation/amortization charges. Advance payments received (including VAT) are recognized under inventories.

Trade receivables and other assets are recognized at their nominal value. Irrecoverable debts are remeasured at the reporting date. The overall non-payment risk is limited by creating a provision for doubtful debts corresponding to 2 percent of the total amount of accounts receivable.

Current marketable securities are recognized at cost.

Cash and cash equivalents are recognized at their nominal value.

Payments made before the reporting date for which the associated benefits will be received in a future period are recognized as prepaid expenses in the balance sheet.

Excerpts from the notes
to the financial statements 2017

The Fraunhofer-Gesellschaft makes use of the instrument provided for in its financial statutes of recognizing a balance sheet reserve, which mainly comprises revenues from the licensing of audio-encoding technologies. The purpose of this reserve is to enable the organization to finance its own pre-competitive research in the medium term.

Funding used to finance non-current assets is allocated to the special reserve for grants relating to non-current assets. A separate special reserve is used to account for grants used to finance current assets.

Provisions for pensions and similar obligations, for which the Fraunhofer-Gesellschaft has a reinsurance policy in place, are measured on the basis of the capitalized amount calculated by the insurance company at the reporting date. The capitalized amounts are calculated in accordance with the information provided by the insurance company and on the basis of DAV 2004 R guideline tables. Adjustments to current pensions and to applicable income are not taken into account. If there is no reinsurance policy in place, or if the settlement cost of the pension obligations exceeds the capitalized amount calculated by the reinsurer, the amount recognized as a provision is calculated in accordance with an expert opinion based on actuarial evidence. The settlement amount of the pension obligation is calculated using the present value method (method for calculating current single premiums). A 10-year-average actuarial interest rate of 3.68 percent was used in the calculation in accordance with Section 253 (2) of the German Commercial Code (HGB), along with the 2005 G guideline tables of Klaus Heubeck.

Other provisions comprise amounts set aside to cover all identifiable risks and contingent liabilities. These provisions are measured in accordance with Section 253 (1) of the German Commercial Code (HGB) on the basis of a reasonable estimate of the most probable outcome. Other provisions for liabilities due in more than one year are discounted at the average market interest rate for loans of a similar maturity as calculated by the Deutsche Bundesbank in December 2017, pursuant to Section 253 (2) of the German Commercial Code (HGB). Provisions for phased early retirement are calculated on the basis of the contracts already concluded and on an estimate of those to be concluded in the future.

Liabilities are measured at the settlement amount.

Payments received before the reporting date for benefits to be delivered in a future period are recognized in the balance sheet as deferred income.

Amounts recognized for transactions in foreign currencies are translated at the applicable hedging rates of the respective currencies. In the annual financial statements, foreign currency holdings are translated at the average spot exchange rate prevailing on the reporting date.

Items in transit are noted as trust assets and trust liabilities in a separate line at the foot of the balance sheet for the Fraunhofer-Gesellschaft.

The following independent auditor's report is based on the balance sheet at December 31, 2017, the income statement for the financial year 2017 and the full notes to the 2017 financial statements and the management report 2017.

INDEPENDENT AUDITOR'S REPORT

We have audited the annual financial statements – comprising the balance sheet, the income statement and the notes to the financial statements – together with the books and records, and the management report of the Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich, for the financial year from January 1 to December 31, 2017. It is the responsibility of the organization's legal representatives to maintain the books and records and to prepare the annual financial statements and management report in accordance with German commercial law. Our task as independent auditors is, on the basis of our audit, to express an opinion of the annual financial statements, including the applied accounting methods, and of the management report.

We conducted our audit of the annual financial statements in accordance with Section 317 of the German Commercial Code (HGB) and the generally accepted standards for the audit of financial statements promulgated by the Institute of Public Auditors in Germany (Institut der Wirtschaftsprüfer, IDW). These standards require that we plan and perform the audit such that misstatements materially affecting the presentation of the net assets, financial position and operating results in the annual financial statements, as prepared in accordance with generally accepted accounting principles, and in the management report are detected with reasonable assurance. Knowledge of the organization's business activities, and of the economic and legal environment in which it operates, together with expectations as to possible misstatements, are taken into account when determining the audit procedures. The effectiveness of the accounting-related internal control system and the evidence supporting the disclosures in the books and records, the annual financial statements and the management report are examined to a large extent on the basis of random samples. The audit includes assessing the applied accounting principles and any significant estimates made by management, as well as evaluating the overall presentation of the annual financial statements and management report. We believe that our audit provides a reasonable basis for our opinion.

Our audit did not lead to any reservations.

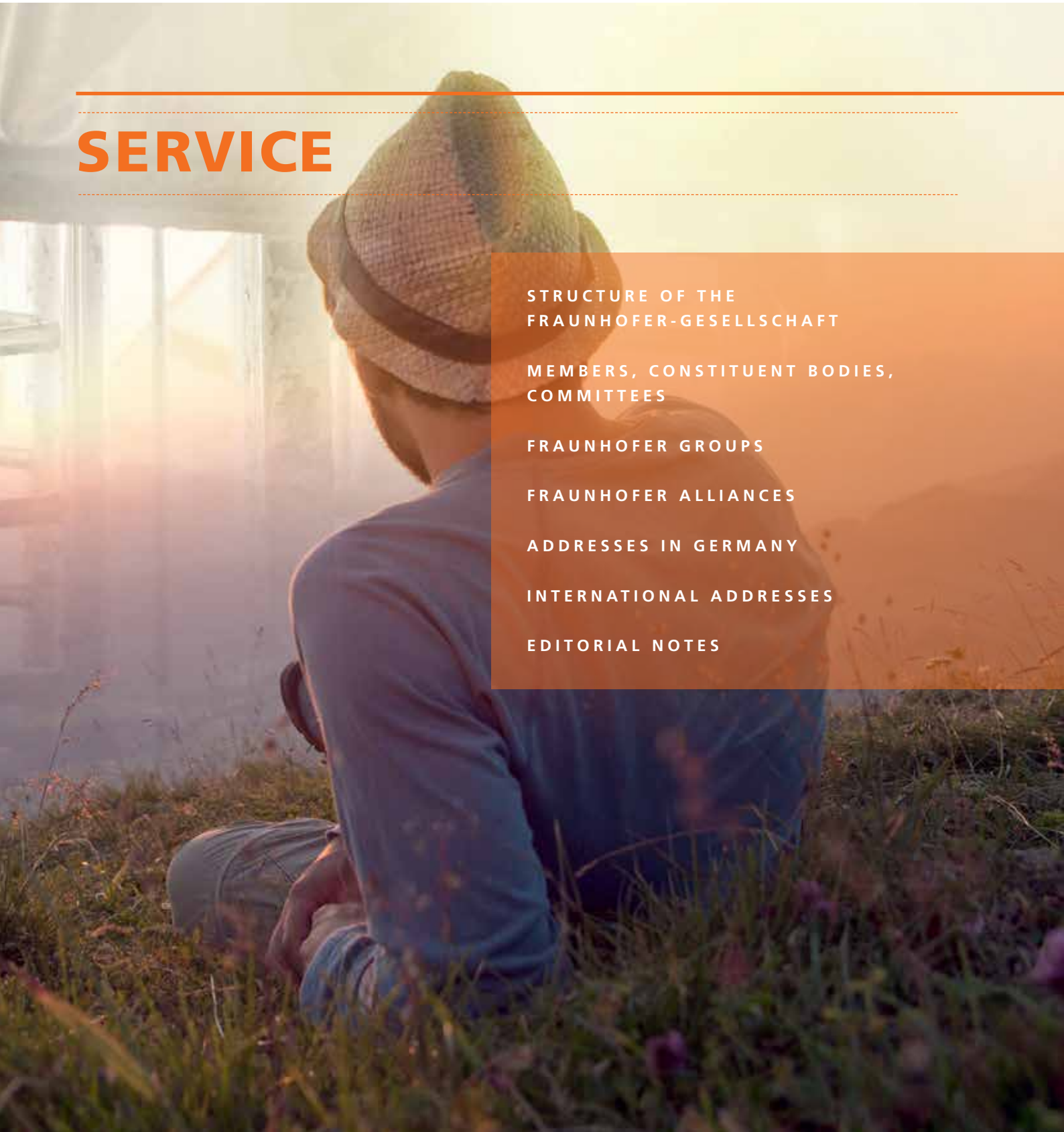
In our opinion, and based on the findings of our audit, the annual financial statements comply with the legal requirements and supplementary provisions of the non-profit organization's Statute and give a true and fair view of its net assets, financial position and operating results. The management report is consistent with the annual financial statements, complies with the statutory requirements and, overall, is a true reflection of the organization's position. It also provides an appropriate picture of the organization's future opportunities and risks.

Nuremberg, March 19, 2018

Rödl & Partner GmbH
Wirtschaftsprüfungsgesellschaft, Steuerberatungsgesellschaft
(auditors, tax consultants)

Vogel	Hahn
Wirtschaftsprüfer (auditor)	Wirtschaftsprüfer (auditor)

The auditor's report issued in German refers not to the foreign language version of the balance sheet and income statement, which are enclosed hereto as appendices, but to the original version of the complete financial statements and management report prepared in the German language.



SERVICE

STRUCTURE OF THE FRAUNHOFER-GESELLSCHAFT

Constituent bodies and their tasks

The **Executive Board** consists of the President and several other full-time members. Its duties include managing the Fraunhofer-Gesellschaft and representing its interests both inside and outside the organization. It formulates the basic principles of the Fraunhofer-Gesellschaft's science and research policy, plans its growth and its finances, ensures its base funding, organizes the distribution of funds among the individual institutes, and appoints the institute directors.

A total of **72 institutes and research institutions** at locations across Germany operate under the umbrella of the Fraunhofer-Gesellschaft. Each cultivates its own market presence and manages its own budget. They are organized in eight **Fraunhofer Groups**, each devoted to a specific area of technology and tasked with coordinating thematically related areas within the Fraunhofer-Gesellschaft and harmonizing the market presence of the respective group members. The chairs of the Fraunhofer Groups, together with the members of the Executive Board, make up the Presidential Council of the Fraunhofer-Gesellschaft. The Presidential Council participates in Executive Board decision-making processes and, as such, is entitled to make proposals and recommendations and has the right to be heard.

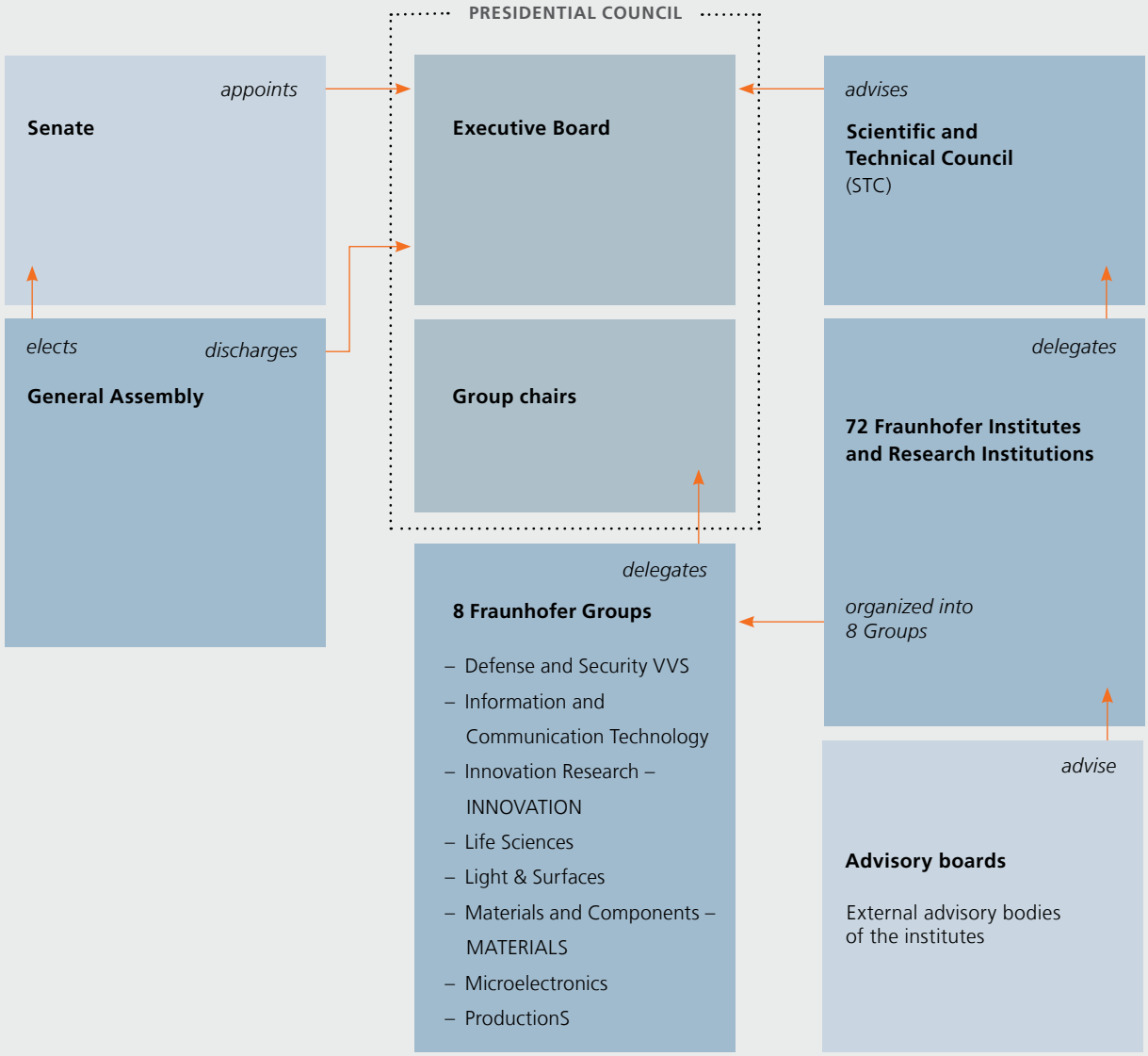
The **Senate** has around 30 members, comprising eminent figures from the worlds of science, business and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The Senate's duties include appointing members of the Executive Board, defining the outlines of Fraunhofer's science and research policy, and formulating decisions concerning the establishment, devolution, merger or dissolution of research entities belonging to the Fraunhofer-Gesellschaft.

The **General Assembly** is made up of the members of the Fraunhofer-Gesellschaft. Official membership is open to members of the Senate, the Executive Board, institute directors and senior management, and the governing boards. Ordinary membership is open to individuals and legal entities who wish to support the work of the Fraunhofer-Gesellschaft. Honorary members may be elected from among the research staff and patrons of the Fraunhofer-Gesellschaft in recognition of outstanding services to the organization. The General Assembly elects the members of the Senate, discharges the Executive Board of its functions, and formulates decisions concerning amendments to the Statute.

The **Scientific and Technical Council** (STC) is the organization's internal advisory body. It consists of the directors and senior management of the institutes and an elected representative of the scientific and technical staff of each institute. The STC provides advice to the Executive Board and other constituent bodies in matters of fundamental importance. It makes recommendations concerning research and HR policy, expresses its opinions regarding the creation of new institutes or the closure of existing institutes, and participates in the appointment of new institute directors.

The **advisory boards** are external advisory bodies of the institutes. They consist of representatives of science, business and public life. For each institute, approximately twelve members are appointed to the advisory board by the Executive Board with the approval of the director(s) of the institute. The advisory boards act as advisors to the institute directors and the Executive Board on matters concerning the research orientation and any structural changes to the institute.

Structure of the Fraunhofer-Gesellschaft



Although the Fraunhofer-Gesellschaft is basically a decentralized organization, its structure also allows for a centrally agreed strategy and effective centralized management. Various constituent bodies and committees are responsible for coordination, consultation and leadership across the organization as a whole.

MEMBERS, CONSTITUENT BODIES, COMMITTEES

Members

The Fraunhofer-Gesellschaft has 1165 members, comprising 213 ordinary members, 942 official members, 2 honorary senators and 10 honorary members. Some members have multiple functions.

Honorary members

- Dr.-Ing. Peter Draheim
- Dr. Alfred Hauff
- Dr. Axel Homburg
- Dr.-Ing. Horst Nasko
- Dr. Dirk-Meints Polter
- Prof. Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Ekkehard D. Schulz
- Prof. Dr. rer. nat. Erwin Sommer
- Prof. Klaus-Dieter Vöhringer
- Prof. em. Dr.-Ing. Prof. h. c. mult. Dr. h. c. mult. Dr.-Ing. E. h. Hans-Jürgen Warnecke
- Dr. rer. pol. Hans-Ulrich Wiese

Senate

Members from the science and business communities, and from public life

- Prof. Dr.-Ing. Heinz Jörg Fuhrmann
  Chair of the Senate of the Fraunhofer-Gesellschaft, Chairman of the Executive Board, Salzgitter AG
- Prof. Dr. phil. habil. Dr.-Ing. Birgit Spanner-Ulmer
  Deputy chair of the Senate of the Fraunhofer-Gesellschaft, Director of Production and Technology, Bayerischer Rundfunk
- Prof. Dr.-Ing. Hubert Waltl
  Deputy chair of the Senate of the Fraunhofer-Gesellschaft
- Dr.-Ing. E. h. Michael von Bronk
  Member of the Management Board, Lausitz Energie Bergbau AG – LEAG
- Prof. Dr.-Ing. habil. Prof. E. h. mult. Dr. h. c. mult. Hans-Jörg Bullinger
  Professor of Industrial Science and Technology Management, University of Stuttgart
- Kerstin Grosse
  Chair of Supervisory Board, KOMSA Kommunikation Sachsen AG
- Dr. Sabine Herlitschka
  CEO and CTO, Infineon Technologies Austria AG
- Reiner Hoffmann
  President of the German Trade Union Confederation DGB
- Dr. Nicola Leibinger-Kammüller
  President and Chairwoman of the Managing Board, TRUMPF GmbH & Co. KG
- Dr.-Ing. E. h. Friedhelm Loh
  Owner and Chairman of the Board of Management, Friedhelm Loh Group
- Hildegard Müller
  Chief Operating Officer Grid and Infrastructure, innogy SE
- Prof. Dr.-Ing. E. h. Hans J. Naumann
  Chairman and CEO, NILES-SIMMONS Industrieanlagen GmbH
- Prof. Dr. Siegfried Russwurm
- Tankred Schipanski
  Member of the German Bundestag, CDU/CSU parliamentary group
- Carsten Schneider
  Member of the German Bundestag, SPD parliamentary group
- Prof. Dr. Wiltrud Treffenfeldt
  Chief Technology Officer Europe, Middle East, Africa and India, Dow Europe GmbH
- Prof. Dr. rer. nat. Christiane Vaeßen
  Managing director, Zweckverband Region Aachen
- Oliver Zipse
  Member of the Board of Management, BMW AG

Members representing government institutions

- MinDirig Hans-Joachim Hennings
  Ministry of Economy, Science and Digitalisation of the State of Sachsen-Anhalt
- MinDirig Dr. Ole Janssen
  German Federal Ministry for Economic Affairs and Energy (BMWi)
- Parliamentary secretary Thomas Rachel
  German Federal Ministry of Education and Research (BMBF)
- Harald Stein
  President, German Federal Office of Bundeswehr Equipment, Information Technology and In-Service Support
- State secretary Annette Storsberg
  Ministry of Culture and Science of North Rhine-Westphalia
- MDirig Dr. Manfred Wolter
  Bavarian Ministry of Economic Affairs and Media, Energy and Technology

Members delegated by the Scientific and Technical Council (STC)

- Prof. Dr. rer. nat. habil. Andreas Tünnermann
  Chair of the STC, Director

of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF
- Dipl.-Ing. Stefan Schmidt
  Deputy chair of the STC, Fraunhofer Institute for Material Flow and Logistics IML
- Prof. Dr. Peter Gumbsch
  Director of the Fraunhofer Institute for Mechanics of Materials IWM

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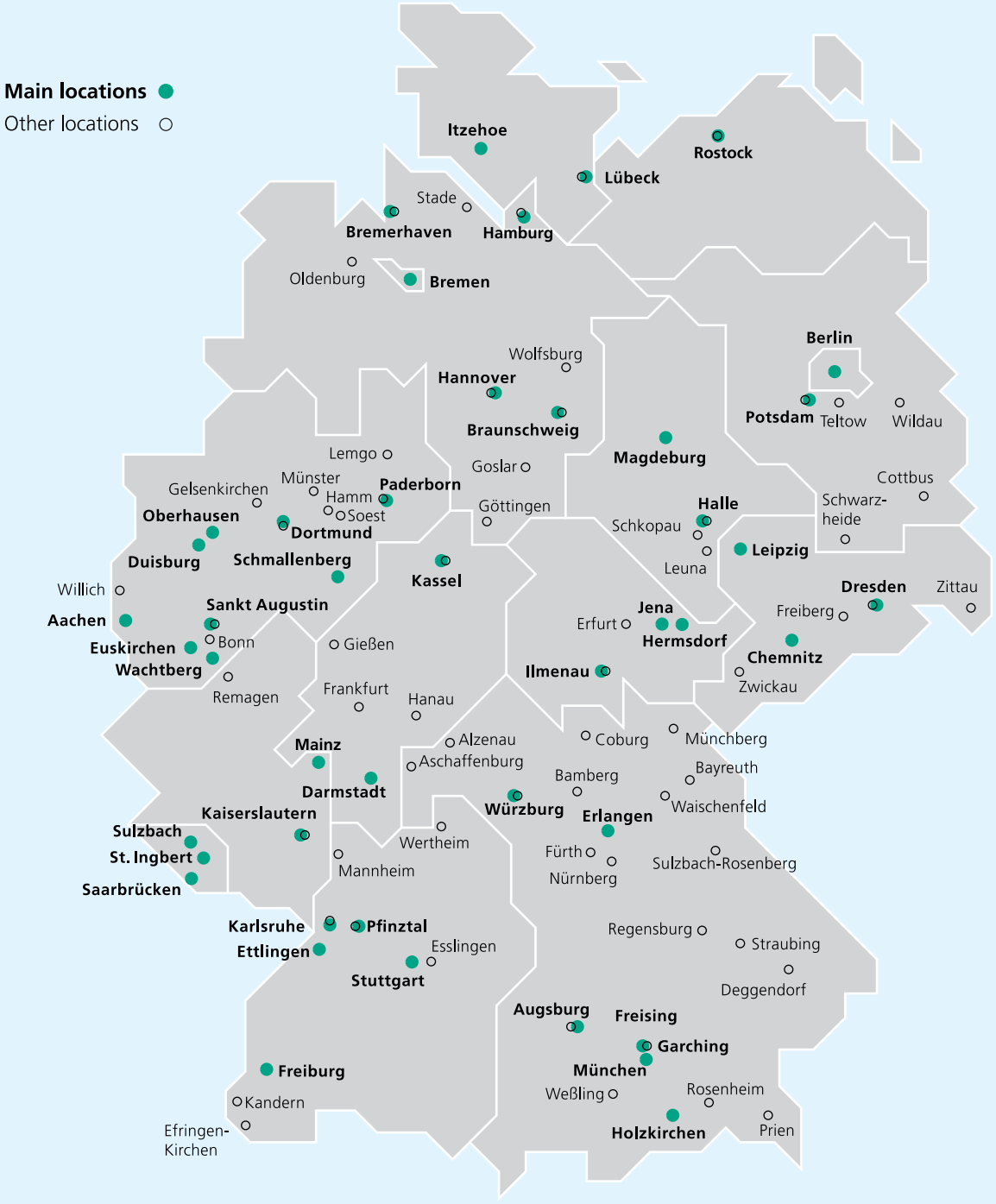
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