

70 YEARS OF
FRAUNHOFER
**70 YEARS
OF FUTURE**
#WHATSNEXT

ANNUAL REPORT
2018

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 26 600 staff are qualified scientists and engineers, who work with an annual research budget of 2.6 billion euros. Of this sum, 2.2 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 2019
www.fraunhofer.de

ANNUAL REPORT
2018



Ladies and gentlemen,

The Fraunhofer-Gesellschaft continued to grow from strength to strength in 2018. Our business volume reached a record high of €2.6 billion. This amounts to a remarkable 12-percent year-on-year increase. We owe this enduringly positive development to a host of successful projects, initiatives and structural measures, in which the expertise, motivation and innovative ideas of our researchers and other employees have been key contributing factors. This growth reflects Fraunhofer's positive image in the eyes of its customers and government sponsors, and its strong position within the scientific community.

The Fraunhofer-Gesellschaft was founded 70 years ago. The motto we have chosen for our anniversary year is "70 years of Fraunhofer. 70 years of future. #WHATSNEXT". It emphasizes our role as an agile and creative research organization, capable of identifying and acting to promote emerging topics before they become mainstream issues for industry and society. We have gained in experience and self-confidence over the past seven decades, but more importantly we are proud of the many achievements that have enabled Fraunhofer to continue growing from success to success. To keep this momentum going, we are developing forward-looking strategies and creating innovative structures that will allow us to respond flexibly, rapidly and effectively to tomorrow's challenges.

An important step in this direction has been the creation, in recent years, of virtual research structures such as the Fraunhofer Clusters of Excellence and the Research Fab Microelectronics Germany (FMD). Given the greater reactivity and pulling power of such structures, they will no doubt play an increasingly important role in the way the Fraunhofer-Gesellschaft organizes its work in the coming years.

The synergies that can be tapped by intensifying internal networking are of inestimable value. The Fraunhofer Digital project which we launched last year will enable us to vastly improve the efficiency of our administrative processes. As an organization with considerable expertise in translating data into knowledge, we are confident that digitalizing our internal administrative processes and implementing business intelligence systems to analyze our data will deliver an enormous increase in efficiency, creativity and know-how. Digitalization will significantly augment the degree of cooperation between individual Fraunhofer Institutes, both in terms of shared data infrastructures and with regard to research projects.

Digitalization is also fundamentally transforming the world of work. Our intention is to proactively influence this development to the benefit of all involved. Through our New Work project, which forms part of the Fraunhofer 2022 Agenda, we aim to implement new ways of working that involve a high degree of virtualization (tools and resources), interaction (people) and flexibility (work place and time, job content). As a result, we will be able to speed up our response to market demands and better accommodate our employees' personal needs and professional strengths. This in turn will raise our profile as an attractive employer for people who think creatively and the "doers and shakers," in other words precisely the people we need to achieve our objectives. And it will help us to maintain and further improve our already excellent reputation as research partners supporting industry and society at large.

It takes major commitment on the part of all employees at the institutes and headquarters to achieve this kind of success. If we approach Fraunhofer's future with the same courage and confidence, we will continue to accomplish great things for applied research and for our customers – and thus for Germany, Europe and beyond.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'R. Neugebauer', with a long horizontal line extending to the right.

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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#WHATSNEXT

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REPORT OF THE EXECUTIVE BOARD

THE EXECUTIVE BOARD

MANAGEMENT REPORT 2018

REPORT OF THE SENATE
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INSIDE THE FRAUNHOFER SENATE

THE EXECUTIVE BOARD

70 YEARS OF
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Reimund Neugebauer is professor of Machine Tools at the Chemnitz University of Technology (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, Technology Marketing and Business Models



After his academic and practical examination in law, Alexander Kurz held positions as manager and board member of 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



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

MANAGEMENT REPORT 2018

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Fraunhofer-Gesellschaft – key data for 2018 (in € million)

	2017	2018	Change	
Business volume by segment	2286	2551	+265	+12%
Contract research	1992	2168	+176	+9%
Defense research	121	128	+7	+6%
Major infrastructure capital expenditure	173	255	+82	+47%
Business volume by budget	2286	2551	+265	+12%
Operating budget	1940	2106	+166	+9%
of which: personnel expenses	1260	1362	+102	+8%
of which: non-personnel expenses	640	698	+58	+9%
of which: change in reserves ¹	40	46	+6	+15%
Capital expenditure budget ²	346	445	+99	+29%
Project revenue by segment	1596	1677	+81	+5%
Contract research	1466	1486	+20	+1%
of which: industrial revenue	711	723	+12	+2%
of which: public-sector revenue ³	755	763	+8	+1%
Defense research	57	60	+3	+5%
Major infrastructure capital expenditure	73	131	+58	+79%
International revenue⁴	279	293	+14	+5%
Patent applications (number)	602	612	+10	+2%
Employees (number)	25,327	26,648	+1321	+5%

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 government, EU and other revenue.

4 Excludes license-fee revenue and revenue generated by legally independent international affiliates through business with third parties (2018: €31 million).

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 industry 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 operates 72 Fraunhofer Institutes and Research Institutions across Germany. The majority of the more than 26,600 people who work for Fraunhofer hold academic degrees in the natural and engineering sciences. Together they generate an annual business volume of €2.6 billion, almost €2.2 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 fields of business and core competencies 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:

- Information and Communication Technology
- Innovation Research – INNOVATION
- 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 relevance to society and sets up in-house programs to move them forward.

Fraunhofer 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 or in science and industry. Students have excellent prospects for a career in industry by virtue of the practical training they receive at Fraunhofer.

At the **international** level, legally independent Fraunhofer affiliates and representative offices in host countries as well as partnerships with research institutions of excellence and innovative companies ensure Fraunhofer direct access to the key regions of present and future scientific progress and economic development.

Strategic initiatives

The Fraunhofer-Gesellschaft has maintained its successful growth strategy, both as a business and as a research organization. This success is visible in its quantitative development and in the increasing qualitative breadth and depth of its R&D portfolio. The organization continues to pursue the goal of further increasing its impact on business and society through excellence and synergies, as stated in its **Fraunhofer 2022 Agenda**. In 2018, these activities focused on introducing instruments and processes to strengthen corporate management, i.e. more intensive centralized coordination of cross-institute research topics at Executive Board level. They include the Key Strategic Initiatives, Fraunhofer Clusters of Excellence and, increasingly, the High-Performance Centers as technology transfer vectors.

The seven areas of strategic importance known as Fraunhofer's **Key Strategic Initiatives (KSIs)**, which form part of the Fraunhofer 2022 Agenda, group together the skills and expertise of multiple institutes in fields of high relevance to business and society such as battery technology, quantum technology or artificial intelligence and data sovereignty. In 2018, management tandems were created between the Fraunhofer Institutes and Fraunhofer headquarters in order to define concrete goals for the Key Strategic Initiatives, for instance to achieve a leadership position in science, to generate significant industrial revenue or to raise social awareness of the topic in question.

The purpose of the **Fraunhofer Clusters of Excellence** is to promote cross-institute collaboration on important research themes. In organizational terms, they could be described as virtual competence centers based on an agile structure spread across several locations. Two new clusters were established in 2018: Circular Plastics Economy and Integrated Energy Systems. They are tasked with developing innovations for plastics recycling and renewable energies.

The 17 **High-Performance Centers** are regionally based and work together with university and non-university partners to support the needs of local industry. In collaboration with their partners – Fraunhofer Institutes, universities, non-university research institutions and local companies – they develop transfer roadmaps and set mutually defined goals. All the High-Performance Centers will be ready for evaluation by mid-2019, marking the end of their two-year pilot stage by mid-2019. In 2018, eight High-Performance Centers received a positive evaluation.

Fraunhofer is exceptionally well connected within the German research community. **Institutionalized cooperation programs involving all four major research organizations** in Germany have been in place since 2018. A new joint transfer funding program with the Deutsche Forschungsgemeinschaft (DFG) was launched in 2018 to promote trilateral cooperation formats between Fraunhofer Institutes, universities and industrial partners. These are primarily of benefit to small and medium-sized enterprises (SMEs), which often have no direct access to basic research. Fraunhofer forms consortia with the Helmholtz Association of German Research Centers and university schools of medicine in a proof-of-concept pilot program to transfer new methods of therapy and diagnostics from pre-clinical research to clinical trials. Four cooperation projects were selected for funding in 2018. Fraunhofer works with the Leibniz Association to implement the investment program for the Research Fab Microelectronics Germany (FMD), which is funded by the BMBF. The cooperation program between Fraunhofer and the Max Planck Society has been in existence since 2005. It addresses high-risk pre-competitive research projects.

Links between Fraunhofer and universities or universities of applied science were further expanded in 2018, based on flexible models adapted to the needs and nature of each partnership. In addition to parallel appointments (90 percent of institute directors simultaneously hold a university professorship), 249 heads of department at Fraunhofer Institutes also have close working ties to specific universities.

A project called **NewWork@Fraunhofer** has been launched to modernize the working environment and generate ideas for future workplace design. Spurred on by the trend toward greater digitalization, this project aims to establish flexible work arrangements that promote agility, networking and independence of place and time. Such changes will improve Fraunhofer's performance, innovative strength and attractiveness as an employer. A review of current practices was completed in 2018, and is to be followed by the piloting of new working concepts in 2019.

Fraunhofer has launched the new **mobility program CONNECT** to enable employees to build up international contacts. It allows Fraunhofer scientists and administrative staff to spend up to six months working abroad at one of Fraunhofer's international locations. This exchange scheme strengthens the global Fraunhofer network and enables employees to gain additional qualifications and skills.

Another initiative started in 2018 is **Fraunhofer Digital**, the aim of which is to build a new, future-oriented research management system with a view to improving internal and external cooperation. One of its objectives is to harmonize and adapt the administrative aspects of all Fraunhofer business processes in order to create corresponding digital processes. In three separate subprojects – Transformation of the ERP System, Business Intelligence, Fraunhofer Data Space – this initiative will help Fraunhofer to combine internal and external data in an intelligent way that will make the organization more innovative and customer-friendly and improve its performance and efficiency. It will enable research managers to rapidly identify correlations between market and customer data and Fraunhofer assets, and in this way improve portfolio management at both corporate and institute level, as well as providing impetus for new business models.

Science policy framework

The German federal government's **High-Tech Strategy 2025**, published in 2018, sums up its ambitions with regard to research and innovation under the motto "Minds, skills, innovation". In concrete terms this means orienting research toward today's most pressing social challenges, developing Germany's expertise in the technologies of the future, transitioning to an innovation culture that is open to risk, and defining 12 missions that will be central to the country's research and innovation policy. The High-Tech Forum, an advisory body comprising representatives of the research and business communities and the general public, will help to implement the High-Tech Strategy 2025 through proposals for its content and strategic development. This consultative committee is chaired jointly by Professor Reimund Neugebauer, president of the Fraunhofer-Gesellschaft, and Christian Luft, state secretary at the German Federal Ministry of Education and Research (BMBF).

In the current legislative period, the **Innovation Dialog** will continue to revolve around new developments and trends on the national and international stage, keeping a close eye on scientific progress and advising the German federal government on aspects of relevance to its innovation and research policy. German Chancellor Angela Merkel renewed Professor Neugebauer's appointment as a member of this steering committee. At a meeting at the German Chancellery on December 3, 2018, the Chancellor herself, research minister Anja Karliczek, minister of economic affairs Peter Altmaier, parliamentary state secretary Helge Braun, and state secretary at the ministry of finance Werner Gatzert, standing in for finance minister Olaf Scholz, came together in the first Innovation Dialog of the current legislative period, along with representatives of research and industry. The main topic of discussion was the strengths and weaknesses of the German innovation system compared with that of other countries. The attendees also discussed how innovative technologies

could be harnessed to solve major societal issues, taking the circular economy as an example.

The banner chosen by the BMBF for its Science Year 2018 was **“Working Life of the Future”** – a topical issue both in the media and among the general public. This subject was raised two years ago by the then research minister Professor Johanna Wanka, speaking at the Fraunhofer annual meeting and directly appealing to the Fraunhofer-Gesellschaft to lend its support. She argued that Fraunhofer was better placed than any other research organization to shape the future of work, both from a technological and a social standpoint. Her successor, Anja Karliczek, has also stressed the importance of communicating research in a way that is understandable to ordinary people. Consequently, the Fraunhofer-Gesellschaft was invited to join the panel of experts tasked with advising the BMBF on its science-year projects.

In October 2018, Fraunhofer held an interactive exhibition in Berlin under the name **Fraunhofer-Erlebniswelt #Zukunftsarbeit**, allowing the public to participate in the ongoing debate and make their own contributions to the agenda that will define our working lives in the future. It demonstrated potential technological solutions developed in Fraunhofer’s laboratories, which could be tested by visitors to the exhibition. Extensive media coverage ensured wider publicity. 21 Fraunhofer Institutes took part in this weeklong event. BITKOM, BMBF, VDMA, DGPF, vdi and gematik also held related events at the Fraunhofer-Forum in Berlin. After Berlin, the Fraunhofer-Erlebniswelt #Zukunftsarbeit hands-on exhibition toured to Brussels and Stuttgart, enabling many more visitors to experience how applied research can help resolve the challenges of tomorrow’s working environment and labor market, and try out these solutions for themselves. A study published by Fraunhofer entitled **“#Zukunftsarbeit – Zukunftsbilder und Handlungsfelder”** provides a summary of these findings and formulates recommendations to guide policy-makers in their decisions concerning future labor

legislation for workers in the manufacturing and healthcare sectors.

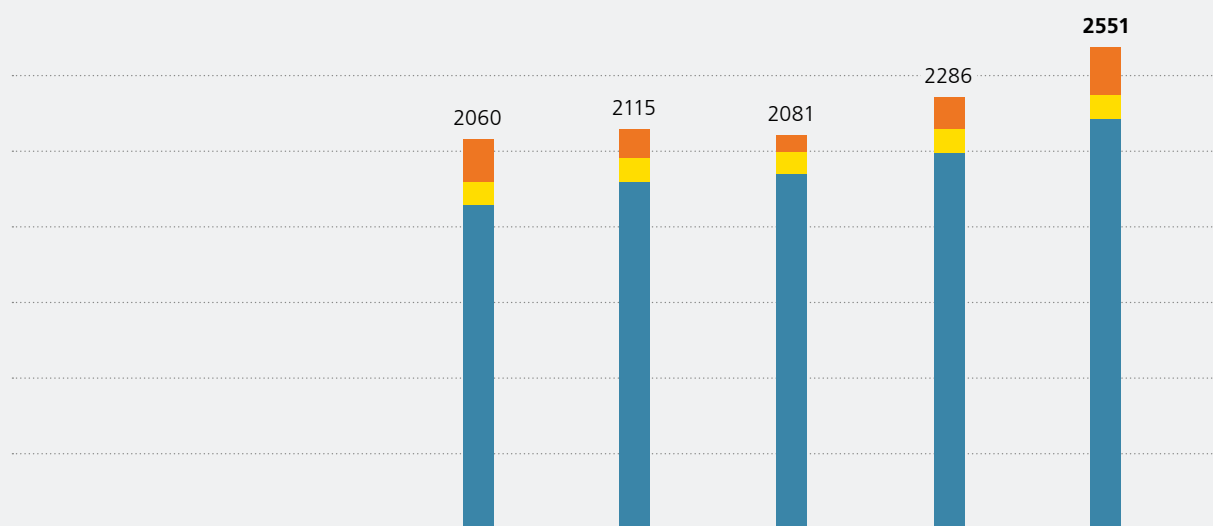
Obtaining funding for education and research remained a key political objective last year. The Fraunhofer-Gesellschaft has been granted additional resources to support this objective. Fraunhofer’s research budget rose once again in 2018. This was a consequence of the 2017 **increase in base funding** (totaling €67 million) from federal and state governments. Under the third phase of the Joint Initiative for Research and Innovation, the BMBF’s contribution to base funding will increase annually by 3 percent. In 2018, this growth in base funding was largely used to finance the organization’s Key Strategic Initiatives. Although base funding has tended to account for a decreasing proportion of the contract research budget in recent years, it has now been restored to a level consonant with the successful Fraunhofer model.

In late 2018, the German parliament’s budget committee approved a resolution to grant an **additional €14.8 million in base funding** to the Fraunhofer-Gesellschaft in 2019 out of the BMBF’s allocated resources. These funds will be used to finance specific projects in the research areas “energy infrastructures and geothermal power,” “smart oceanography” and “translational medicine to treat neuroinflammation”. Fraunhofer intends to work out strategic concepts for their implementation in the course of the 2019 financial year.

In 2018, the German Federal Ministry of Education and Research (BMBF) and the State of Hesse announced that the **Center for Research in Security and Privacy (CRISP)** in Darmstadt, created in 2015, is to be expanded to form a new center of excellence named National Research Center for Applied Cybersecurity. Institutional funding will be made available as of the beginning of 2019 by the BMBF and the State of Hesse.

BUSINESS REPORT

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



	2014	2015	2016	2017	2018
Business volume by segment	2060	2115	2081	2286	2551
■ Contract research	1716	1835	1879	1992	2168
■ Defense research	118	127	114	121	128
■ Major infrastructure capital expenditure	226	153	88	173	255
Business volume by budget	2060	2115	2081	2286	2551
Operating budget	1664	1783	1853	1940	2106
of which: personnel expenses	1093	1142	1193	1260	1362
of which: non-personnel expenses	586	612	619	640	698
of which: change in reserves ¹	-15	29	41	40	46
Capital expenditure budget ²	396	332	228	346	445

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, 2018 was a very successful year for Fraunhofer. Compared with the prior year, business volume increased by 12 percent to €2551 million, with all three segments posting substantial growth. Contract research accounted for €2168 million, defense research for €128 million and major infrastructure capital expenditure for €255 million. Project revenue also rose by 5 percent, totaling €1677 million across all segments. The three segments will be discussed in greater detail in the following sections.

Business volume is based on the 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 along with the change in the special license-fee revenue reserve. 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 2018, capital expenditure accounted for a greater portion of business volume than in the previous year. With capital expenditure totaling €445 million, Fraunhofer invested 29 percent more year over year, marking a return to the level of earlier years. The personnel expenses recognized in the operating budget rose by 8 percent to €1362 million, an increase that was due to workforce growth of around 1300 employees (up 5.2 percent) and to a 3.2 percent wage increase granted as of March 1, 2018 under the collective wage agreement for the public sector. At €698 million, non-personnel expenses were around 9 percent higher year over year. The special license-fee revenue reserve increased by €46 million.

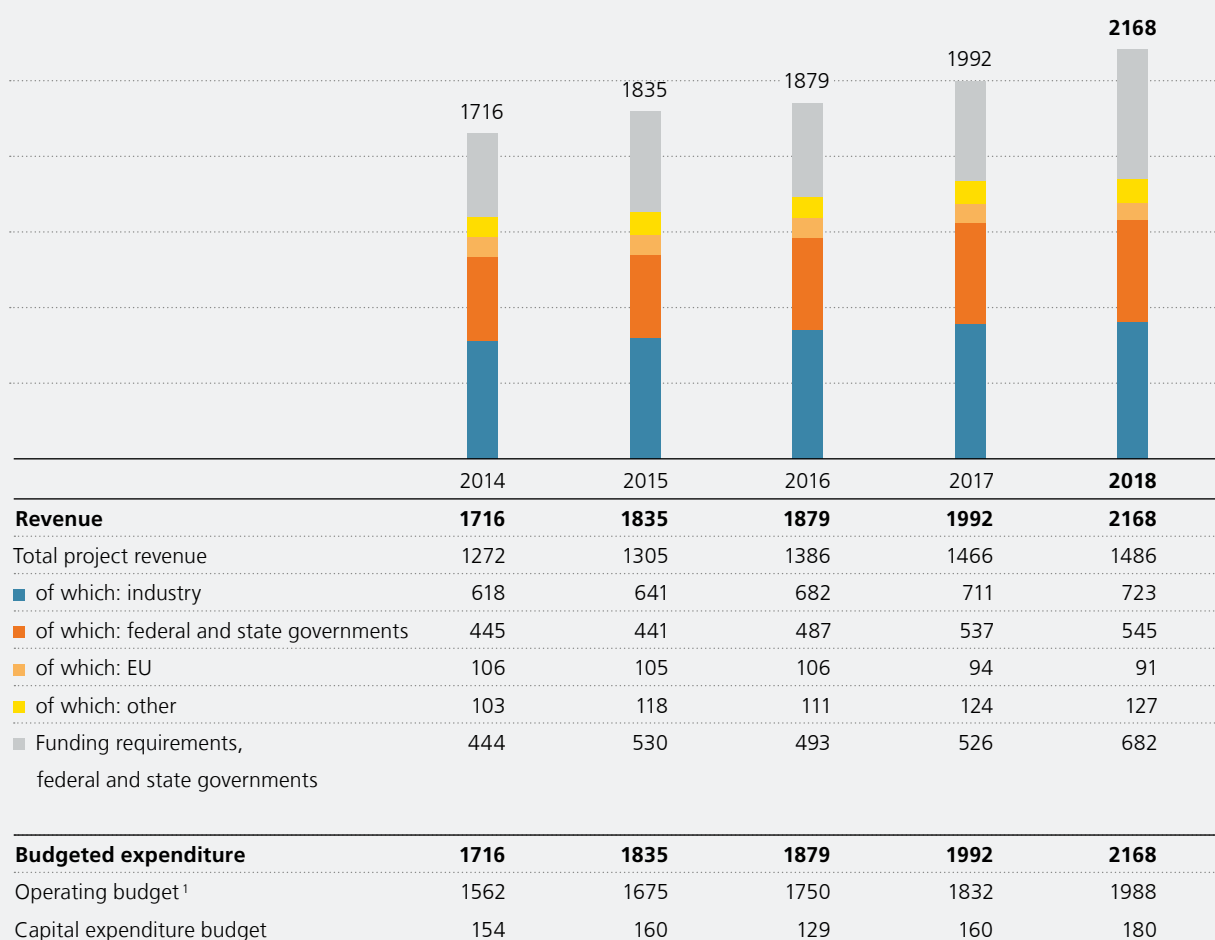
Contract research

Accounting for about 85 percent of business volume, contract research is the mainstay of Fraunhofer's business activities. In accordance with the organization's mission statement, contract research includes research conducted on behalf of industrial enterprises, publicly funded projects and pre-competitive research financed with base funding. Base funding 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 9 percent year over year to reach €2168 million in 2018. Of that total, the operating budget accounted for €1988 million, up 9 percent, and current capital expenditure for €180 million, up 13 percent. Growth was mainly financed through base funding. The funding requirement rose by 30 percent to €682 million. Fraunhofer uses this to implement important initiatives, such as the establishment of Fraunhofer Clusters of Excellence, new lighthouse projects and Key Strategic Initiatives.

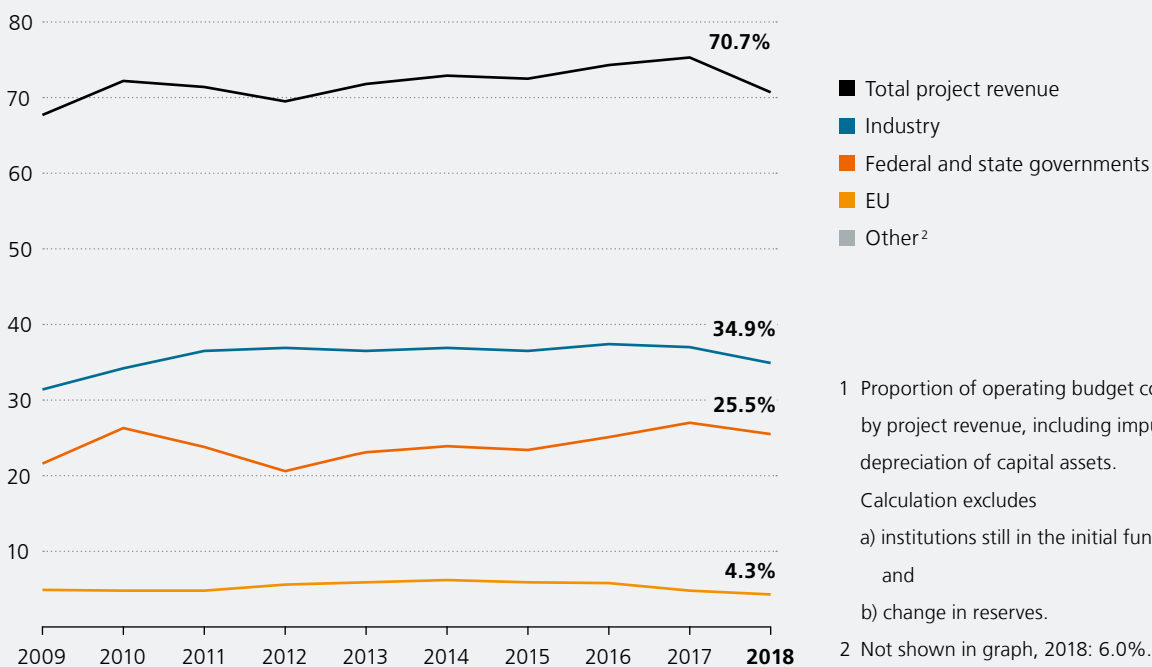
In line with Fraunhofer's funding model, two-thirds of contract research is financed through project revenue, which totaled €1486 million in 2018. Industrial revenue rose by 2 percent to €723 million. Of that sum, revenue from contracts with industry increased significantly, rising by 8 percent to €614 million. At €109 million, license-fee revenue, by contrast, was lower than the previous year's figure due to expired contracts. Revenue from project funding granted by the federal and state governments grew by 1 percent to €545 million. Of this sum, €395 million came from the federal government and €150 million from the state governments.

Contract research: Revenue and budgeted expenditure (in € million)



¹ Includes change in the special license-fee reserve (2018: €46 million, 2017: €40 million).

Contract research: Project funding ratio ¹



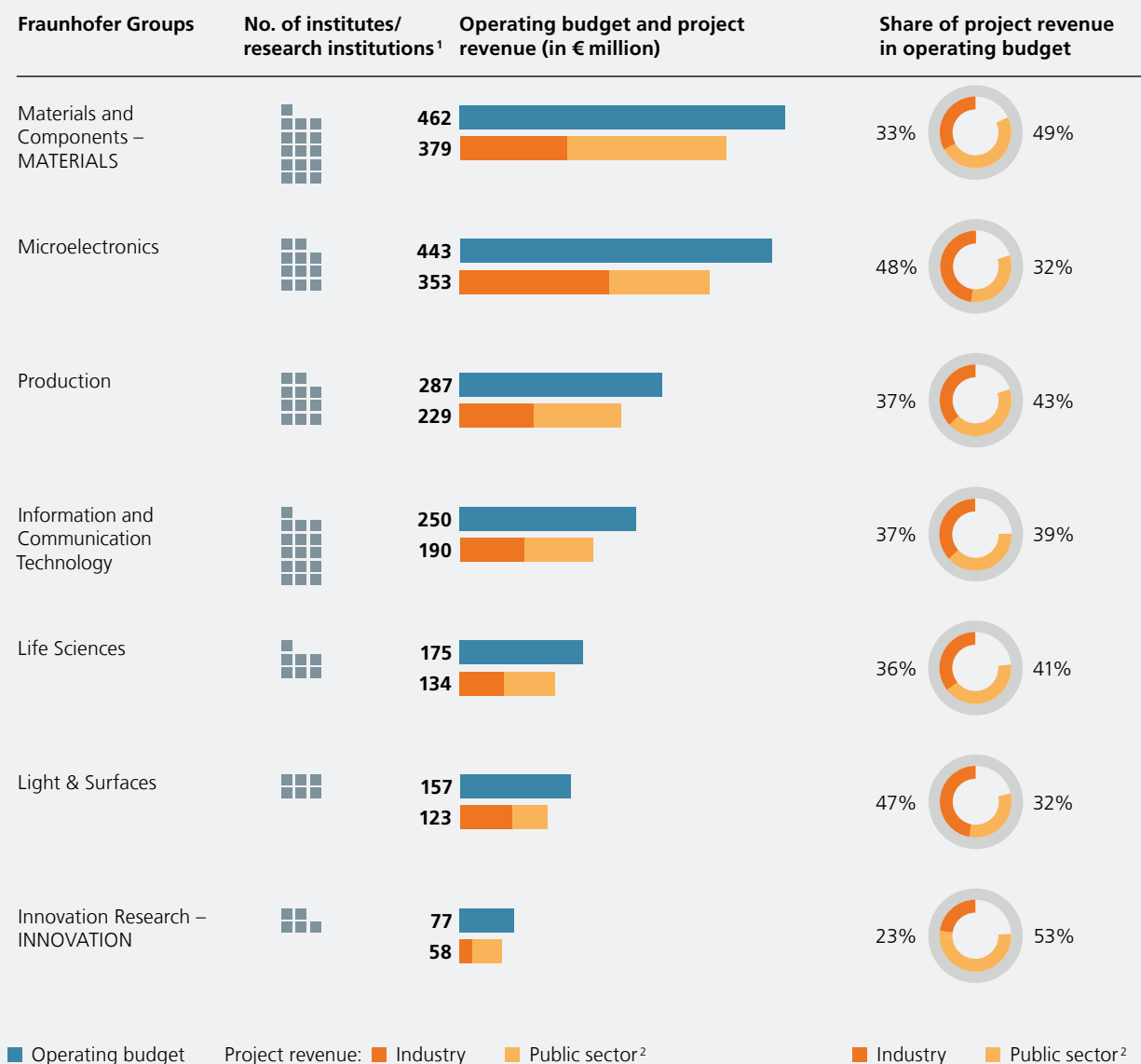
- 1 Proportion of operating budget covered by project revenue, including imputed depreciation of capital assets. Calculation excludes
a) institutions still in the initial funding period and
b) change in reserves.
- 2 Not shown in graph, 2018: 6.0%.

EU revenue decreased slightly to €91 million. Although revenues from the Horizon 2020 Programme (funding period 2014 to 2020) have been rising, they have still not reached the same level as during the funding periods for previous EU Research Framework Programmes. Other revenue stood at €127 million.

The high proportion of the operating budget covered by externally acquired project revenue is a criterion for the success of the Fraunhofer Institutes and also a unique feature of the Fraunhofer-Gesellschaft, as well as an indicator of a balanced funding mix in contract research.

Due to sustained strong growth, project revenue has accounted for a steadily increasing share of the operating budget over the past several years, whereas the proportion covered by base funding has tended to decline. The increase in base funding in 2018 brought the funding mix back into line with the targets of the successful Fraunhofer model. In total, the proportion of the operating budget covered by project revenue was 70.7 percent. Industrial revenue covered 34.9 percent of the operating budget. Project funding from the federal and state governments accounted for 25.5 percent, EU revenue for 4.3 percent and other revenue for 6.0 percent.

Contract research: Performance statement of the Fraunhofer Groups 2018



1 As at January 1, 2019; includes contract research carried out by the seven defense-related Fraunhofer Institutes.

2 Comprises federal and state government, 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.

With an operating budget of €462 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 €443 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 49 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 48 percent.

The Fraunhofer Group for Innovation Research – INNOVATION established in 2017, which now has five member institutes, continued to develop positively in 2018 and achieved an operating budget of €77 million, up 10 percent. The high share of its operating budget covered by public-sector revenue (53 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 military or terrorist security threats. 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 €128 million. Of that figure, €118 million was accounted for by the operating budget, which increased by 9 percent, and €10 million by capital expenditure. This budget growth was attributable to project funding and base funding in almost equal measure. Revenue from project funding increased by 5 percent to €60 million, while the amount required from base funding rose by roughly the same extent to €68 million.

Including its contract research activities, the Fraunhofer Group for Defense and Security VVS had an operating budget of €213 million, 16 percent of which was covered by industrial revenue and 48 percent by public-sector revenue.

Defense research: Budgeted expenditure and revenue (in € million)

	2014	2015	2016	2017	2018
Budgeted expenditure	118	127	114	121	128
Operating budget	102	108	104	108	118
Capital expenditure budget	16	19	10	13	10
Revenue	118	127	114	121	128
Project funding, BMVg	58	64	49	57	60
Funding requirements, BMVg	60	63	65	64	68

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

	2014	2015	2016	2017	2018
Capital expenditure budget	226	153	88	173	255
■ Building projects (major and minor)	179	118	62	98	132
■ Equipping of new facilities	47	35	26	27	34
■ Research Fab					
Microelectronics Germany (FMD)				48	89
Revenue	226	153	88	173	255
Project funding, ERDF ¹ and other	54	28	16	25	42
Project funding, BMBF for FMD				48	89
Funding requirements, federal and state governments	172	125	72	100	124

1 ERDF = European Regional Development Fund.

Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises building projects and equipping of new facilities with scientific instruments and furniture. This segment also includes 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 €255 million in 2018.

This amount includes €89 million for scientific instruments for the FMD, 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 upgrade the corresponding portfolio of laboratory equipment.

Compared with prior years, capital expenditure on building projects and the equipping of new facilities was substantially higher in 2018. Capital expenditure on building projects rose by a total of €34 million to €132 million year over year, €104 million of which was for major and €28 million for minor projects. Capital expenditure on the equipping of new facilities rose by €7 million to €34 million.

Special funding for major building projects (and their equipment) is provided by the federal government and the government of the 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 2018 totaled €124 million. ERDF funds from the states accounted for €29 million of project revenue, while €13 million was accounted for by other revenue.

Financial and net asset position

As at December 31, 2018, the Fraunhofer-Gesellschaft had total assets of €3446 million, up €260 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 accounting for the remaining 0.5 percent.

Non-current assets accounted for 62 percent of assets and were €155 million higher at €2136 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 €127 million to €2060 million.

Current assets accounted for 35 percent of assets and were €24 million higher at €1217 million. This slight increase was mainly attributable to a reduction of €22 million in cash and cash equivalents (including bank account balances), which totaled €163 million at the reporting date. Of that figure, €69 million was carried forward under the terms of the management statutes. The securities portfolio increased by €46 million and, at €385 million, corresponds to the license-fee revenue reserve. Receivables from the federal and state governments in relation to project billing decreased by €11 million.

Equity – which comprises the non-profit organization's capital that is not financed by government grants (€15 million) and restricted reserves (€1 million) – increased by a marginal amount. Economic equity also includes three kinds of special reserve recognized in the balance sheet: The special reserve for grants relating to non-current assets was €156 million higher at €2121 million. The special license-fee revenue

reserve grew by €46 million to €385 million. The special reserve for the present value of deferred income from a patent deal came in at €69 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 not included in economic equity and is used to account for income not yet received, less expenses not yet paid, by the reporting date. This essentially corresponds to advance project financing and amounted to €265 million at the reporting date.

Provisions increased by €16 million to €174 million, €38 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 €72 million were entered on the assets side of the balance sheet.

Liabilities climbed by €27 million to €415 million. This increase was mainly due to a net rise of €23 million to €298 million in unappropriated grants from the federal and state governments (base funding) and receivables in connection with 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 **90 companies** across a wide variety of sectors. The transfer of technology to industry formed the focus of activities at 66 of the companies in the investment portfolio, while a further 18 equity investments were of a strategic nature. There are also six affiliated companies. There was considerable activity in Fraunhofer's investment portfolio in 2018. Overall, the organization spent some €1.2 million to acquire equity interests. The Fraunhofer-Gesellschaft added 11 companies to its investment portfolio and divested its shares in 6. The total carrying amount of equity investments (including shares in affiliated companies) increased to €9.3 million (2017: €8.8 million). Income from the divestiture of equity investments came to €3.2 million.

Spin-offs are an integral part of Fraunhofer's strategy for exploiting its industrial property rights. The Fraunhofer Venture department typically provides support to spin-off founders during preparation for launch. In individual cases, Fraunhofer takes a minority share in the spin-off company as part of the technology transfer process. In 2018, Fraunhofer Venture provided support to 39 new spin-off projects; in total, 30 new businesses were spun off from the Fraunhofer-Gesellschaft. Fraunhofer's goal is to increase not only the number of spin-offs but also their percentage contribution to industrial revenues. Our technology transfer program AHEAD offers a comprehensive package of targeted measures and programs to help achieve this.

International activities

In order to strengthen Germany's role as a hub for research and innovation, Fraunhofer seeks and establishes collaborations with excellent partners worldwide. Fraunhofer's internationalization strategy is based on the principle of creating scientific value for Fraunhofer and generating positive effects both for Germany and Europe and for 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 various formats for generating excellent scientific content and cooperating with attractive international partners. The eight legally independent **international Fraunhofer affiliates** 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.

The legally independent international affiliates function as the legal entities for the – currently 16 – research centers outside Germany. The latter are institutionalized Fraunhofer partnerships with local universities, with the aim of 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 host country. As their work is not profit-oriented, the affiliates generally qualify for base funding from the host countries, and they are financed in line with the Fraunhofer funding model.

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 2018:

The Fraunhofer Project Center for Advanced Lightweight Technologies FPC@OUTech, a partnership between Fraunhofer IWU and Opole University of Technology in Poland, develops lightweight hybrid components, in particular for the automotive industry.

To conduct research into a new generation of drugs, researchers from Fraunhofer IGB are pooling resources with teams from the Hebrew University of Jerusalem in the Fraunhofer Project Center for Drug Discovery and Delivery FPC_DD@HUJI. The aim is to prevent viruses and bacteria from proliferating before the latent infection presents any outward symptoms.

Developing new strategies to protect data, IT systems and critical infrastructures from unauthorized access is the aim of the Fraunhofer Project Center for Cybersecurity FPC_CS@HUJI, a partnership between Fraunhofer SIT and the Hebrew University of Jerusalem.

Fraunhofer's internal program **ICON** (International Cooperation and Networking) enables strategic project-based partnerships with international universities and non-university research organizations of excellence. In 2018, the ICON program was instrumental in initiating six new partnerships with leading centers of excellence on five continents:

As part of an ICON project, Fraunhofer ILT, in partnership with the National Institute of Advanced Industrial Science and Technology (AIST) in Japan, is developing an ultra-efficient semiconductor manufacturing process that enables particularly effective and compact electronic applications.

The University of Leiden in the Netherlands is cooperating with Fraunhofer IME and Fraunhofer ISC in the ICON project BioSensing, which focuses on the development of a new generation of biosensors based on DNA-stabilized metal quantum clusters for use in biomedicine as well as in the food and environmental sectors.

The Lawrence Berkeley National Laboratory in the U.S. is collaborating with Fraunhofer ISE on an ICON project in the field of energy-efficient construction and digital support of building and construction planning processes.

The aim of the ICON project being conducted by Fraunhofer IME and Monash University in Australia is to analyze food ingredients and what happens to them during production, processing and metabolization with a view to improving health-related information on food labeling.

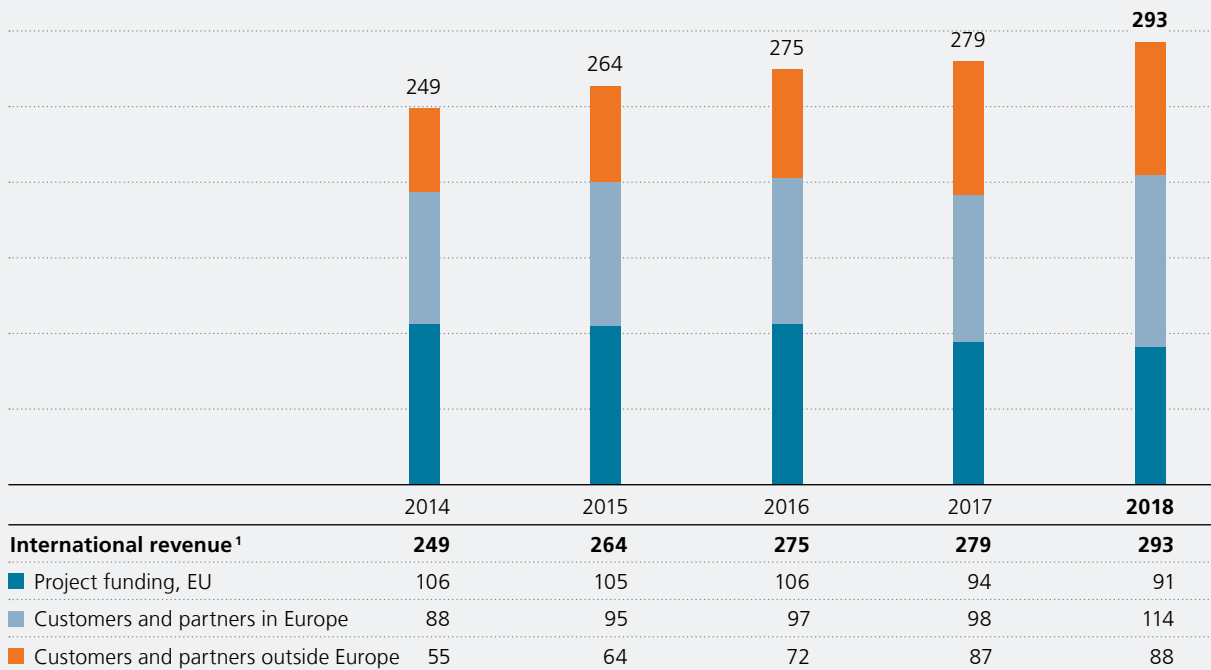
In a partnership with the Korea Institute of Materials Science (KIMS), Fraunhofer IKTS is working within the scope of the MultiFuncCer ICON project on qualifying an additive manufacturing process for ceramic components, known as lithography-based ceramic manufacturing (LCM), for multi-material applications.

In the WASTEC ICON project, the Fraunhofer Institutes IST, ISE, IGB and IOSB, together with Stellenbosch University, are developing processes for the treatment and usage of water in order to establish solutions to the water supply problems in South Africa and the sub-Saharan countries.

Consistently high levels of **international revenue** are an indicator of Fraunhofer's success in the global research market. In 2018, the organization's international revenue rose by 5 percent to €293 million (excluding license-fee revenue). Some 31 percent of international revenue came from EU funds, 39 percent from customers and partners in Europe, and 30 percent from those outside Europe.

The **EU Commission** is a key source of funding and, through its participation in the Horizon 2020 Framework Programme, the Fraunhofer-Gesellschaft plays an active role in shaping Europe's economic and research environment. In terms of funding received, Fraunhofer ranks third among the participating institutions. Nevertheless, EU revenue decreased slightly in 2018 to €91 million. Although revenues from Horizon 2020 (funding period 2014 to 2020) have been rising, they have still not reached the same level as during the funding periods for previous EU Research Framework Programmes.

The Fraunhofer-Gesellschaft's international revenue (in € million)



¹ Excludes license-fee revenue and revenue generated by legally independent international Fraunhofer affiliates with third parties (2018: €31 million).

In total, the Fraunhofer-Gesellschaft's revenue generated with customers and partners in **Europe** came to €114 million in 2018. Switzerland was the largest European market, at €25 million, followed by Austria (€21 million) and the Benelux countries (€19 million). At €88 million, revenue generated **outside Europe** was slightly higher than in the previous year. Despite a slight decline due to the completion of major projects, the United States remained the most important non-European market, generating revenue of €27 million. In Asia, Fraunhofer achieved revenue growth of 9 percent. Here, with revenues

of €19 million and €17 million respectively, China and Japan were the largest non-European markets after the U.S. In addition to the international revenue generated by the Fraunhofer-Gesellschaft, the legally **independent international Fraunhofer affiliates** also realized third-party revenues totaling €31 million. Of this amount, Fraunhofer USA, Inc. alone accounted for €14 million, followed by the Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik (in Sweden) and Fraunhofer Austria Research GmbH, each with €4 million.

Intellectual property activities

Fraunhofer remains the leader among German research institutions in terms of the 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. Similar statistics compiled by the European Patent Office (EPO) have also placed Fraunhofer among the most active patent applicants.

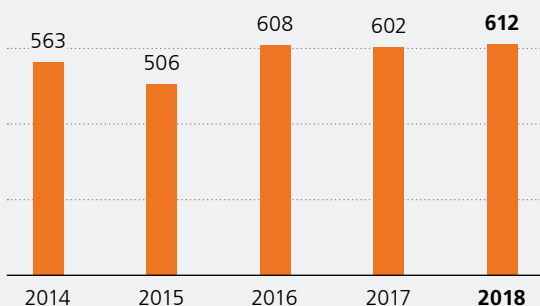
In 2018, employees of the Fraunhofer-Gesellschaft submitted 734 invention disclosure reports. Of these, 612 were filed with the relevant patent offices as patent applications claiming rights of priority, which corresponds to a rate of almost three patent applications filed each working day. Fraunhofer’s portfolio of active patent families, each of which comprises all actionable rights in different countries, rose to 6881. The total number of patents granted to Fraunhofer in Germany was 3272.

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.

Fraunhofer generates revenue from the commercialization of intellectual property (IP) 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 2018, Fraunhofer concluded 384 new licensing agreements, bringing the total number of active licensing contracts at the end of the year to 2515. Due to the expiry of a number of licensed patents, license-fee revenue declined year over year in line with expectations and amounted to €109 million in 2018.

Patent applications claiming rights of priority



CORPORATE RESPONSIBILITY

Employees

At year-end 2018, Fraunhofer had 26,648 employees, 18,913 of whom were research, technical or administrative staff (RTA staff), 7225 students, and 510 trainees. That corresponds to a year-over-year increase of 5.2 percent or 1321 employees in 2018. In other words, the rate of increase has risen significantly compared with the already high rate of 3.6 percent in 2017.

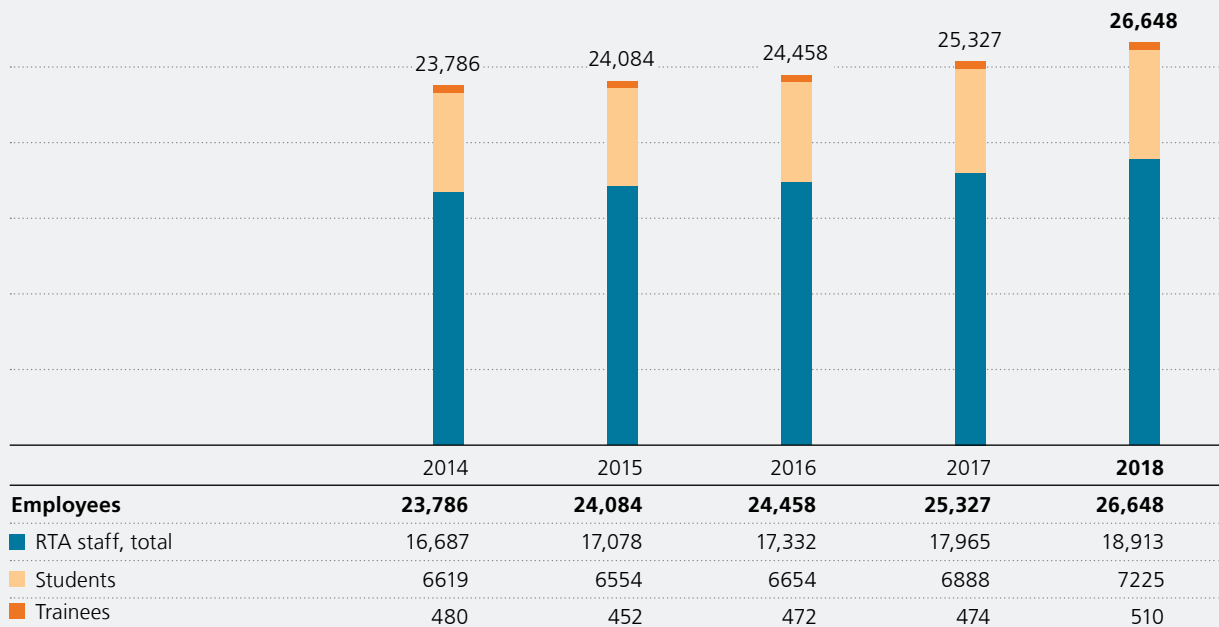
In accordance with its mission statement, the Fraunhofer-Gesellschaft offers its employees the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility either at Fraunhofer or in other areas of science or industry. This approach, which builds 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 professional development. 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 occupation in industry or science, but also for starting up spin-offs.

Given this policy of encouraging knowledge transfer, Fraunhofer's high employee turnover rate among RTA staff is a positive phenomenon. In 2018, 1600 RTA staff left the organization, while 2548 new employees were taken on. Some 56 percent of new recruits were young researchers embarking on their career. Overall, at year-end 2018, Fraunhofer employed 10,331 scientists, accounting for 55 percent of all RTA staff.

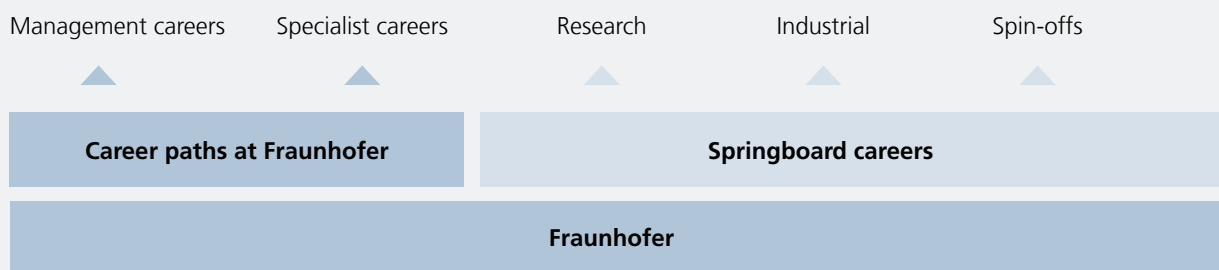
The **guidelines on short-term contracts** launched in 2013 are being systematically implemented at the Fraunhofer Institutes. In recent years, targeted discussion of the topic and sustained monitoring helped reduce the proportion of research employees on short-term contracts by 4 percentage points to 59.2 percent at year-end 2018. The ratio of technical and administrative employees and research support staff on short-term contracts was 29.4 percent. Overall, 45.7 percent of RTA staff are employed on short-term contracts. Around 11 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. On the basis of this, Fraunhofer submitted a Human Resources Strategy for Researchers (HRS4R) to the EU Commission and about a year ago was granted the right to use the EU's **HR Excellence in Research** logo. In awarding the logo, the Commission singled out for praise the working conditions at Fraunhofer, the career opportunities for young researchers and the high-caliber research environment. This certification confirms the high quality of Fraunhofer's HR policy.

Vocational training is an integral part of Fraunhofer's personnel development strategy. The diversity of career opportunities is reflected in the wide range of dual vocational training courses and study programs on offer, through which Fraunhofer provides training in 49 recognized professions covering 6 occupational categories and hosts 17 dual study programs. Of the organization's 510 trainees, 455 are enrolled on dual vocational training courses, 24 on dual study programs with a focus on academic training, and 31 on dual study programs with a focus on practical training.

Employees (number at year-end)



Career paths at Fraunhofer and springboard careers beginning at Fraunhofer



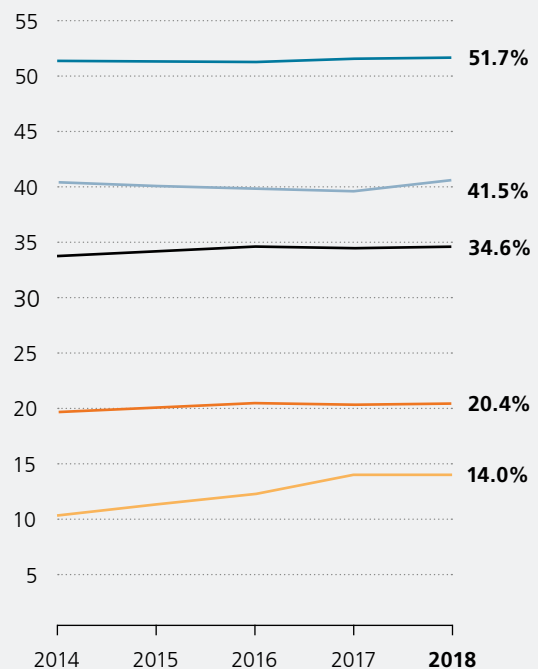
Diversity

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.

Fraunhofer has set itself the goal of increasing the proportion of women in scientific and management posts, as part of its **equal employment opportunities** program, and diversifying the composition of teams with a view to promoting scientific excellence, knowledge-sharing and innovative capacity. The measures applied to achieve this objective follow a strict set of guidelines which together form a systematic approach to creating equal opportunities for all. The TALENTA program is a key element in this effort to recruit more female scientists for a career at Fraunhofer and encourage them to stay by offering support at different stages of their professional development. One of the projects carried forward in 2018 in connection with the Fraunhofer 2022 Agenda aims to help more women obtain tenure-track appointments as associate or full professors (W2/W3 level), giving them the prospect of climbing higher up the academic ladder and increasing the proportion of women in top scientific positions (“gender-appropriate excellent careers”). This systematic approach to supporting women who wish to pursue a career in science forms part of an all-round concept which also includes respecting different cultural values and enabling women to balance their family and work commitments.

At the end of 2018, **ratio of female scientists** to men among research staff at Fraunhofer was 20.4 percent, in other words, we fell short of our self-imposed target of 21.6 percent by a narrow margin. To achieve a more substantial increase in the percentage of female researchers, Fraunhofer will have to make an even stronger commitment to the recruitment

Ratio of women to men in different categories of RTA staff



- Total RTA staff
- Technical and administrative staff
- of which: Management
- Research staff
- of which: Management¹

¹ Excluding heads of institutes and directors.

of young female talent. By contrast, the proportion of women in technical and administrative posts is comparatively high (51.7 percent). Averaged over all categories of RTA staff, the ratio of women to men in the Fraunhofer workforce is 34.6 percent.

Given the intense competition to recruit **women for management posts**, especially in business and industry, Fraunhofer was unable to increase its proportion of female research managers (level 2: below that of institute director) in 2018. In the course of exit interviews and personal conversations with women who had chosen to leave Fraunhofer, in particular those who had been pursuing an internal career development program, it was possible to elucidate some of the main reasons for their departure. The private sector is aggressively seeking to lure the best candidates by offering significantly higher pay and perks such as a company car – conditions that Fraunhofer cannot compete with.

This explains why the fluctuation rate for women at this level of management (level 2) is four percentage points higher than for men. In both cases, the fluctuation rate compared with 2017 has increased by 1.5 percentage points. This would indicate that, in the current economic situation, the terms of employment offered by private industry appeal to men and women in equal measure, and this is causing higher staff turnover in the public research sector.

At the end of 2018, Fraunhofer had 539 more research scientists on its payroll than one year previously, 451 of whom (84 percent) **hold posts that do not carry hierarchical management responsibility**. Unfortunately, despite top employer rankings and excellent scores in internal and external surveys, Fraunhofer was for the first time unable to meet its target of recruiting women in the same proportion as the relative number of female graduates in the five main disciplines of interest. Possible reasons why this target wasn't reached

in 2018 include the very high increase (10 percent) in the number of employees at this level of the organization, combined with intense competition for female graduates by private industry. Fraunhofer will continue to explore and analyze these hypotheses. Meanwhile, it can only be assumed that the job opportunities available to new graduates in private industry at the present time are so enticing that it will be much more difficult for Fraunhofer to attract female scientists, especially given the current state of the labor market.

Beyond that, Fraunhofer is aspiring to increase **the ratio of women on its scientific advisory** 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 2018, the corresponding figure was 17 percent – with the mandates of those sitting on more than one advisory board being counted individually. In the Fraunhofer Senate, the organization's highest steering committee, women accounted for 33.3 percent of the elected members.

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 2018, the ratio was 2.8 percent. Management has a particularly important role to play when it comes to the topic of inclusion. Specific management guidelines on this subject were therefore developed in 2018. They provide advice on how to adapt recruitment, induction and career development processes to the needs of the disabled and suggest ways of facilitating their integration. This initiative was flanked by additional support for employees seeking information on inclusion, both as a general issue and more specifically for managers.

Social commitment

Many Fraunhofer employees support charitable causes sponsored by the institutes they work for, for instance by participating in the blood donation drive organized by the Fraunhofer Institute Center in Stuttgart and by the four institutes based in Dresden.

Above and beyond such campaigns, Fraunhofer recognizes that 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 their potential employers. That is why Fraunhofer has developed a plan to integrate refugees via three different channels: internships, training positions and RTA staff positions.

The plan will be tailored to the specific requirements of each host 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 mentors in accordance with their particular needs. Implementation of the plan began in Saxony in 2016, with Baden-Württemberg and Bavaria following in 2017. Since the program was launched, more than 100 refugees and displaced persons have been taken under the wing of Fraunhofer Institutes, mostly on orientation courses. We are particularly pleased that one of our first protégés, a young woman of 25, is about to complete her training. It was her own hard work, including intensive language courses, and many helping hands among her colleagues at Fraunhofer, that made this possible.

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. The Fraunhofer-Gesellschaft publishes regular sustainability reports, detailing its goals, measures in place and information on each area of corporate responsibility. In this context, since 2017, Fraunhofer has published an annual statement 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 Fraunhofer-Gesellschaft fulfilled this requirement by producing a **corporate responsibility progress report for 2018**, which was published in early 2019 and sent to important external and internal stakeholders, as well as being posted on the Fraunhofer website.

The newly constituted **Corporate Responsibility Board** took up its duties in 2018. As a central body placed above the Executive Board and the institute directors, it takes a comprehensive view of all CR-relevant issues, allowing them to be integrated into the organization-wide strategy development process. Its current focus lies on the NewWork@Fraunhofer initiative and the question of health management for the upper tier of management.

Research and development

Many of Fraunhofer's research activities are aimed at resolving today's most challenging societal issues, e.g. in the domains of environmental protection, energy and agriculture. Further measures taken to reinforce the efficacy of these solutions include the creation of efficient research and transfer structures as part of the **Fraunhofer 2022 Agenda**, closer collaboration between Fraunhofer Institutes and a greater emphasis on interdisciplinary research.

One of the key elements of the 2022 Agenda is the establishment of **Fraunhofer Clusters of Excellence**, initially for a period of five years and devoted to specific areas of research. Their purpose is to promote scientific excellence and reach a wider international audience by enabling groups of Fraunhofer Institutes to work together on a longer-term basis. In 2018, five of the six clusters approved so far took up their work. One of these is the Fraunhofer Cluster Circular Plastics Economy. It consists of five Fraunhofer Institutes and its aim is to demonstrate ways in which energy and material streams can be managed in a closed cycle, with specific reference to the plastics industry. Its work includes developing system solutions tailored to the needs of the plastics industry and the companies that market the resulting consumer products, with a view to recycling.

The **transition to a sustainable energy economy** also plays a big role in the research conducted by the Fraunhofer-Gesellschaft. In 2018, the non-profit association Open District Hub e.V. was founded as a platform on which Fraunhofer and reputable industry partners can drive forward the digitalization of the energy sector. The idea is to develop system solutions for fully integrated and automated cross-sector applications. The ultimate objective is to optimize the combination of different energy sources and balance supply and demand at a local level, so as to ensure a reliable energy supply while at the same reducing CO₂ emissions.

In the **Fraunhofer Cognitive Agriculture lighthouse project (COGNAC)**, for short, launched in 2018, eight Fraunhofer Institutes have joined forces to develop concepts for future, more efficient and sustainable farming practices. Their vision is a digitalized world in which farmers can achieve high productivity while respecting environmental prerogatives such as sustainability, efficient use of natural resources and high product quality. This can be done using ultramodern sensor technology to collect, analyze and process environmental and operational data, allowing farm managers to take fact-based, sustainable decisions.

In 2018, as part of the **F4D – Fraunhofer for Development** program to bring Fraunhofer expertise to bear in the international development arena, Fraunhofer set up the SAIRA open innovation platform in cooperation with WAITRO, the World Association of Industrial and Technological Research Organizations. The platform connects players in the applied research sector with private enterprise and public institutions so that they can work together to tackle the United Nations' Sustainable Development Goals. These projects address issues such as climate change, ensuring a reliable food supply and the eradication of infectious diseases.

Citizen science plays an increasingly important role at Fraunhofer, reflecting the organization's desire to conduct research not only for the wider public but also hand in hand with public participants, thus integrating them into the research and innovation process. The term "citizen science" is used to describe projects in which amateur scientists or volunteers work alongside professional researchers on scientific topics of current or popular interest. In 2018, Fraunhofer was involved in 5 of the 13 projects funded by the BMBF under its program to support citizen science. The subjects covered range from urban farming and research into rare diseases to the development of environmental sensors and concepts for smart headphones.

Resources and procurement

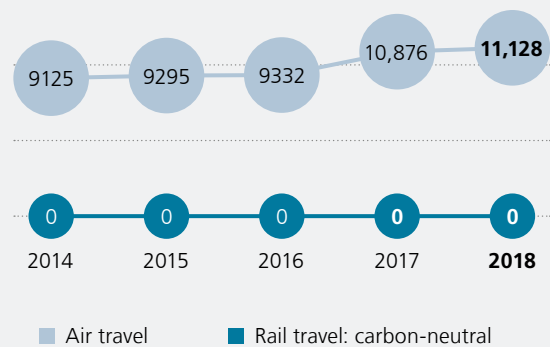
In accordance with the requirements of the German Energy Services Act (EDL-G), Fraunhofer conducted its first **energy audit** at all locations in 2015. Such audits must be carried out once every four years. The individual institutes are responsible for implementing, on an ongoing basis, the energy-saving measures recommended in the audit. The next audit is scheduled for 2019 and will be coordinated centrally and carried out according to uniform guidelines.

As regards the procurement of products and services, all tenders for new master agreements and projects are, wherever feasible, tied to product- and service-specific social and **ecological criteria**. As a result of this strategy, around 19 percent of Fraunhofer's total electricity consumption of 209,064 MWh in 2018 was derived from renewable resources.

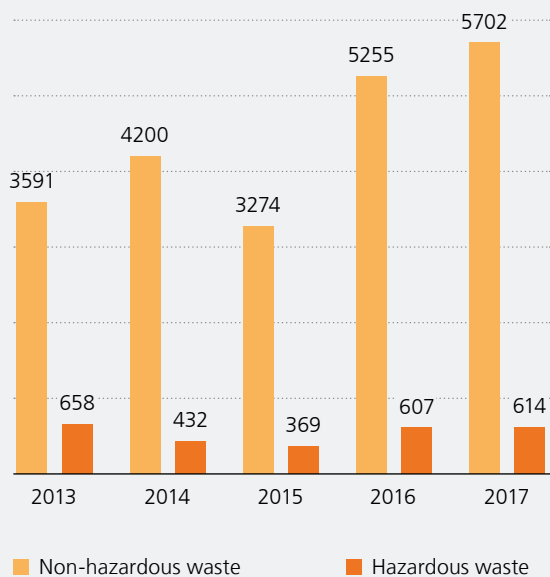
Fraunhofer collects data annually on the **CO₂ emissions** its employees generate through business trips by train and plane. As in previous years, the total number of business trips increased slightly in 2018 due to the rising number of employees and to the growing volume of research. Thanks to the framework 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 CO₂ emissions from air travel amounted to around 11,128 metric tons in 2018, or roughly 0.4 metric tons of CO₂ per employee.

The Fraunhofer Institutes have appointed site officers to handle **operational waste management** at the individual locations and to document their activities in a waste register and corresponding yearly report. The latest statistics can be found in the Fraunhofer Corporate Responsibility Progress Report 2018, published in early 2019. In 2017, the organization generated 5702 metric tons of non-hazardous waste and 614 metric tons of hazardous waste. Most hazardous waste relates to specific projects and thus varies from year to year.

CO₂ emissions from business travel by Fraunhofer employees (in metric tons)



Volume of waste produced by Fraunhofer Institutes (in metric tons)¹



¹ Source: latest statistics from Fraunhofer Corporate Responsibility Progress Report 2018.

RISK SITUATION AND OUTLOOK

Risk management and risks

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 **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.

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 non-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. Fraunhofer continuously optimizes its strategy planning processes to enable it to identify and evaluate new research topics and future areas of relevance to societal needs early on. Regular evaluation and quality assurance of the internal research programs helps to ensure targeted allocation of funds to relevant research topics.

Fraunhofer transfers the results of its research – for example in the form of patents and intellectual property rights – into existing companies or its own start-ups. This provides an additional source of revenue for Fraunhofer, either through the subsequent disposal of the equity investments or through contract-research income. The performance 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 legally independent international affiliates. Fraunhofer USA, Inc., an international Fraunhofer affiliate, is currently engaged in legal action with a company in the United States for the alleged infringement of intellectual property rights.

The monitoring 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 from the federal and state governments at a level in keeping with its mission and in proportion to its performance, and to ensure management conditions suited to research work. The current management statutes enable Fraunhofer to act flexibly, efficiently and autonomously. If this option were curtailed, it would limit Fraunhofer's liquidity and its ability to make provision for risks, and restrict its flexibility.

In the area of public-sector projects, funding instruments and funded research themes 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 external market developments impacting on 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. Furthermore, Fraunhofer strives to ensure uniform and flexible funding conditions for building 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 achievement.

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.

Provision of modern research infrastructure is an essential prerequisite for implementing innovative research projects. To maintain and upgrade the basic structure of existing facilities, Fraunhofer draws on in-depth studies and action plans to identify buildings potentially in need of refurbishment and develop appropriate financing solutions.

Modern, high-performance IT systems help to streamline business processes in research management. Fraunhofer meets potential organizational challenges arising from the migration to a new ERP system through structured project management and controlling, as well as by increasing the number of temporary staff in the central departments.

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.

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 existing compliance management system has been further expanded through the introduction of an anonymous whistleblower system.

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

The Fraunhofer-Gesellschaft will continue to grow in 2019, both in terms of revenue generation and the number of employees. This **growth** is not a declared goal of the Executive Board, but results from the systematic inclusion of topical research issues and the development of demand-led solutions for industry and society. In terms of revenue generation, Fraunhofer is anticipating another successful year, with total business volume expected to rise by 10 percent to €2.8 billion. Major infrastructure capital expenditure is likely to surge by about 50 percent to around €390 million, mainly driven by the ongoing backlog of major building projects. Budgeted expenditure for contract research is expected to rise by 5 percent to €2.3 billion. Growth will be driven equally by increased project revenue and rising funding requirements from base funding.

Dynamic and market-oriented development of the R&D portfolio is an essential element of Fraunhofer's success. Therefore, parallel to the risk-minimizing, bottom-up development of research topics through the strategy planning processes of the respective institutes, and their complementary coordination at the corporate level, an additional methodological **technology intelligence process** is being developed and implemented. This links the aspects of structured key content extraction, thematic analysis, evaluation and recommendation, ensuring that the selection of new key areas of research is both scientifically based and transparent.

In 2019, Fraunhofer will continue to step up the pace of the ten projects launched under the auspices of the **Fraunhofer 2022 Agenda**, so as to keep up with the latest new developments. Projects that have been successfully completed or have a long-term orientation can be continued at Fraunhofer within a different framework using a quality-assured process, so as to enable new projects such as NewWork@Fraunhofer to be included in the Agenda.

Fraunhofer's extensive and still expanding portfolio requires effective internal structuring and transparent external communication. A **Future Commission** has therefore been set up to examine whether the present organizational structure, comprising 8 Fraunhofer Groups and 72 Fraunhofer Institutes and Research Institutions, will remain viable in the future. The Executive Board and a number of institute directors are currently developing proposals and concepts for new internal organizational models designed to enhance cross-institute collaboration and promote a more coherent image of the Fraunhofer brand and the services it has to offer. They will present the new proposals by the end of 2019.

One of the Fraunhofer-Gesellschaft's future goals is to support the **economic restructuring of the brown-coal-mining regions of Germany**. As a member of the coal exit commission, Fraunhofer had previously contributed substantially to innovation projects in these regions, with the support of local Fraunhofer networks, for example in reality labs that are intended to form the nucleus for new, long-term industrial structures.

Fraunhofer regards the **"70 years of Fraunhofer"** anniversary in 2019 as a success story and at the same time as an incentive to continue to actively shape the future of European research and of Germany as a business hub.

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 in 2018.

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

REPORT OF THE SENATE ON THE FINANCIAL YEAR 2018

In 2018, the Fraunhofer-Gesellschaft intensified its role as the motor of innovation in Germany and throughout Europe. At a time when the European Union is faced with a growing number of challenges, Fraunhofer's revenue from contract research conducted in collaboration with European partners increased by €20 million. The organization's total operating budget grew by more than 11 percent, demonstrating how highly the Fraunhofer-Gesellschaft continues to be valued as a partner to business and industry and to government policy-makers – and even increasingly so.

The Fraunhofer-Gesellschaft's solid financial statements for 2018 again received an unqualified audit certificate from the independent auditors.

In 2018, 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 15 at the AMERON Hotel ABION Spreebogen in Berlin and on October 10 at the Fraunhofer-Forum in Berlin.

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

- The Senate approved the proposal to create the Fraunhofer Tech Transfer Fund, in the form of a limited liability company, with funding from the European Investment Fund totaling €60 million. This fund will allow the Fraunhofer-Gesellschaft to offer more sustainable financial support to spin-offs and licensing projects at an early stage of the commercialization process, and thus expedite the targeted transfer of research findings to marketable applications. This move will also directly benefit the Fraunhofer Institutes, because they will be able to increase their industrial revenues in the long term through spin-offs and new licensing models. The approval of this initiative was initially conditional upon the German federal government's authorization. This was confirmed in a letter from the German Federal Ministry of Education and Research (BMBF) dated December 6, 2018. The official documents needed to create Fraunhofer Technologie-Transfer Fonds GmbH were signed on December 14, 2018.



- The Senate furthermore approved the proposal to expand the organization’s thematic research areas by creating a National Research Center for Applied Cybersecurity (CRISP), with permanent base funding by the federal government and the state of Hesse. The national research center was established on January 1, 2019. It is jointly managed by the Fraunhofer Institutes for Secure Information Technology SIT and for Computer Graphics Research IGD, both based in Darmstadt, in cooperation with Technische Universität Darmstadt and Darmstadt University of Applied Sciences. This unique and innovative combination of university and non-university research will serve as a model for future Fraunhofer ventures of this kind. The former Center for Research in Security and Privacy (CRISP) is being expanded to create a national research center and center of excellence for application-oriented research focusing on the pressing issues of cybersecurity. Its mission includes helping companies to develop solutions and developing its own innovative solutions. It also facilitates cutting-edge research to the benefit of society, business and government.
- In 2017, the Senate elected Dipl.-Kfm. Andreas Meuer to the Executive Board for a five-year term of office, commencing on January 1, 2018. As of January 1, 2019, Mr. Meuer will be responsible for the newly created Executive Board function for Controlling and Digital Business Processes in addition to finances and the far-reaching digitalization process in the Fraunhofer-Gesellschaft.
- Prof. Dr. rer. nat. Georg Rosenfeld, who for just under three years until December 31, 2018 held the function of Executive Vice President, Technology Marketing and Business Models, has relinquished this post by mutual agreement and at his own request. Professor Rosenfeld is leaving Fraunhofer to take up new professional challenges in industry. The Senate thanks him for his successful work and engagement as a member of the Executive Board.

To close, I would like to warmly thank the Executive Board and all employees of the Fraunhofer-Gesellschaft, on behalf of the Senate, for their hard work and performance in the financial year 2018.

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

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 the profile of a newly elected senator.



PÄR MALMHAGEN B.A.

Pär (Pelle) Ole Håkan Malmhagen is the president of Tower International, one of the world's largest automotive suppliers. This leading figure in the global automotive industry joined the Fraunhofer Senate in January 2019.

Pelle Malmhagen has overall responsibility for Tower's North American business, and until recently its European business. The main focus of the company's operations is the manufacturing of chassis structures, vehicle body components and complex assemblies for automakers such as Audi, BMW, Daimler-Chrysler, Fiat, Ford, GM, Jaguar, Land Rover, Seat, Skoda, VW and Volvo. Tower International was formed in 1993, with headquarters in Livonia, Michigan, U.S.A., but its roots can be traced back to the industrial revolution. The 1903 Cadillac was the first car to be produced on a steel frame, in a factory that is still in operation today as part of Tower's production network. Until the group sold off its European operations in March 2019, it produced pressed components and complex welded structures at the Sachsenring factory in Zwickau, which employed around 4000 people.

During his tenure as president of Tower Europe, from 2012 to 2017, Pelle Malmhagen strengthened the group's regional management, built up customer loyalty, and introduced light-weighting technologies. Before joining Tower International, Malmhagen worked for Autoliv Inc., the world's largest automotive safety supplier, in a succession of senior international management positions.



"We are about to witness a period of wide-ranging social changes on an unprecedented scale and happening at a helter-skelter pace. These disruptive changes are being driven by a generation of 'millennials' who grew up in the connected world and take the internet and all its ramifications for granted. As a member of the Fraunhofer Senate, I hope to guide these changes in the right direction. My personal contribution will stem from my international experience in the automotive sector, which is of particular importance to Germany's economy."

REVIEW OF FRAUNHOFER RESEARCH

EUROPE AS A KNOWLEDGE-BASED ECONOMY –
FRAUNHOFER AS AN ENGINE OF INNOVATION

FROM INVENTOR TO VISIONARY FORCE –
THE FUTURE ROLE OF THE FRAUNHOFER-GESELLSCHAFT

NEW INITIATIVES AND INFRASTRUCTURES

PROJECTS AND RESULTS 2018

AWARDS 2018

VISIONS OF THE SHAPE OF THINGS TO COME

PEOPLE IN RESEARCH

FRAUNHOFER INSTITUTE SPIN-OFFS







EUROPE AS A KNOWLEDGE-BASED ECONOMY – FRAUNHOFER AS AN ENGINE OF INNOVATION

Helmuth Trischler

The Lisbon Agenda

Back in March 2000, at the dawn of a new millennium, the European Council met up in Lisbon, the capital of Portugal. Inspired, perhaps, by the chiliastic mood of the times, European heads of state set about drawing up a long-term plan for the future of the European Union. This would become known as the Lisbon Agenda and was based on a strategic triangle linking the creation of new jobs with economic reforms and the promotion of greater social cohesion. At the heart of this extremely ambitious vision was a desire to bring about a shift to a digital economy founded on knowledge. Europe was to become “the most dynamic and competitive knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion and respect for the environment.” Here, the European Council took up an idea promulgated by the European Commission but a few months earlier, namely the creation of a European Research Area to complement a European Higher Education Area. The establishment of the latter was a key objective of the so-called Bologna Process in 1999. Europe would be transformed into an integrated area of knowledge production. As such, the effect of the Lisbon Agenda was to recast the cardinal question as to what constituted the core of European identity and transfer it to the field of science and technology.

In the run-up to Lisbon, the European Commission had consulted a number of prominent researchers in the areas of science, technology and innovation. Among them was Manuel Castells, the oft-cited author of “The Information Age” trilogy (1996–1998), who contributed his ideas on the development of a digital economy based on information and communications technology. Also consulted were the economists Giovanni Dosi, Christopher Freeman, Bengt-Åke Lundvall, Richard Nelson, Carlota Perez and Luc Soete, who emphasized the key role of innovation based on science and technology.

After Lisbon, the traditional grand narrative of a united Europe based on political and economic integration was replaced with a new story about Europe as a knowledge-based economy. According to this alternative narrative, cooperation in science and technology would radically alter European society. At the same time, the guiding idea of a knowledge-based economy would lead Europe to a new affirmation of its identity based on its historically accumulated cultural foundations.

Meanwhile, however, the focus has shifted. The lofty vision of Europe as a knowledge-based economy has been put on hold – replaced by the urgent need, in the wake of the 2008 stock market crash, to stabilize the world’s financial markets. Today, the European refugee crisis – or, in other words, the integration crisis – has combined with a revival of nationalism and the debates surrounding Brexit to place a question mark over the monumental project of European integration. Yet Europe should not lose heart. More than ever, Europe must continue to remind itself of the long and great tradition of cross-border cooperation between scholars and engineers and the contribution they have made to the transnational circulation of knowledge. The project of European integration first appeared on the political agenda with the Treaty of Rome, back in 1957. Yet the consolidation of knowledge within Europe began at a much earlier date, albeit hidden from view.

Europe as a knowledge-based economy – Fraunhofer as an engine of innovation



The mechanism of scientific and technical internationalization

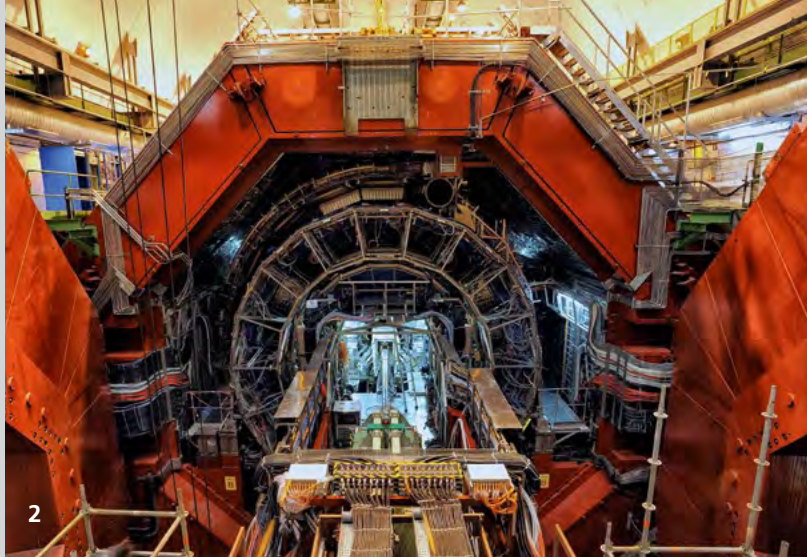
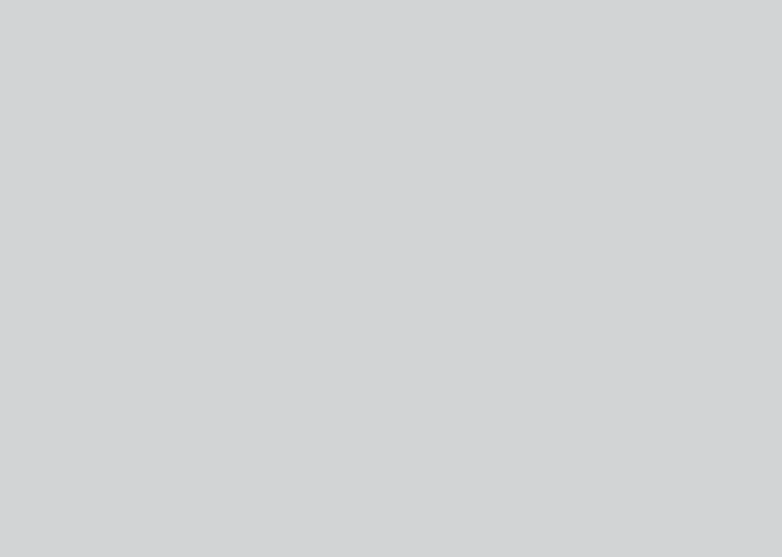
As I have explained in detail elsewhere, this process can be traced back to the Great Exhibition of the Works of Industry of All Nations, which opened its doors in May 1851. Held at the Crystal Palace, which was specially built for the occasion in London's Hyde Park, it was the moment that Europe invented the tradition of the World Expo. Over the coming decades, the general public would be treated at regular intervals to a showcase of all the latest technological achievements from an international community of experts in the worlds of science, technology, trade and commerce. The Great Exhibition attracted six million visitors. It was more than just a technical and industrial show; it was a place where knowledge was shared and exchanged. It provided experts from all manner of fields with an opportunity to study the latest technological developments and, in turn, use that new knowledge to advance industrialization back home in their own country. In Europe's gradually emerging community of knowledge, the Great Exhibition of London and the world expositions that followed were a fixed date where experts could meet and discuss challenges and problems of transnational significance. In 1889, the Paris Exposition Universelle provided the framework for no less than 78 of the 79 international scientific congresses taking place that year.

In London, in 1851, and Paris, in 1889, there was a mechanism at work that would unfold its full dynamism during the second half of the 19th century. This was a process of internationalization that aimed at a standardization of weights and measures, money and time, and the technical infrastructure, such as telegraphy and the railroad, that played a key role in a world increasingly shaped by industrialization and globalization.

One-and-a-half centuries lie between London of 1851 and Lisbon of 2000. Over that period, scientific and technical experts were involved in hundreds of thousands of cooperative ventures on the European level. This transnational collaboration between individuals and institutions gave rise to a shared European experience and what may properly be called a European history.

This cooperation on the scientific and technological level was never a linear process leading to a steady growth of transnational networks and institutions. On the contrary, this story of Europe built on cooperation and the circulation of expertise is driven by the tensions of what Eric Hobsbawm called the "age of extremes," in which Europe was the seedbed of two world wars. During these two wars, the circulation and exchange of scientific and technical knowledge fell drastically, only to revive again with all the more vigor after 1945.

Indeed, the numerous initiatives in postwar Europe to institutionalize transnational cooperation in science and technology can only be properly understood on this basis. These efforts, which first came to fruition with the establishment of CERN in 1952, had many roots. One of these was the idealistic belief that scientific and technical cooperation would help heal the wounds of the Second World War and establish peace in Europe. Key, too, was the U.S.'s postwar drive for hegemony. This meant forging alliances with, for example, the European Atomic Energy Community (Euratom). The aim here was twofold: to prevent individual European states from going it alone in sensitive areas such as nuclear technology, and to maintain access, during the Cold War period, to European allies' scientific and technical resources. In Europe, too, cooperation was almost always the result of a concrete political desire on the part of the postwar nation states to bolster their standing on the world stage.



In other words, European cooperation in science and technology always involved more than merely joint projects to build particle accelerators, spacecraft and fusion reactors. The hope, too, was that these flagship projects would enable postwar Europe to showcase its scientific and technological prowess to the rest of the world.

In 1967, the U.S. journalist Jean-Jacques Servan-Schreiber wrote a celebrated essay that was translated and published in English as “The American Challenge”. It launched a pivotal debate on the “technology gap” between Europe and the U.S. Today, we know that this gap was already starting to narrow by then. The essay did, however, unleash a broad public debate. In response, Europe’s political elite launched a volley of scientific and technical initiatives, ranging from the establishment of COST (Cooperation in Science and Technology) in 1970 and the European Science Foundation in 1974 to provisions in the Maastricht Treaty of 1993 that gave the European Commission extensive powers in the area of research funding. In 1984, the Commission also launched the first of what have been, to date, eight framework programs for research, each running for a number of years. Funding has exploded over the years, rising from €3.3 billion for the initial program (1984–1987) to almost €80 billion for the current Horizon 2020 program.

1 *Crystal Palace, London, home to the Great Exhibition of 1851.*

2 *Particle accelerator CERN, 1952.*

The initial Europeanization of the Fraunhofer-Gesellschaft in the 1980s and 1990s

What part has the Fraunhofer-Gesellschaft played in this process of Europeanization? Has it used the opportunities this presented in an essentially pragmatic, passive manner? Or has it been active in driving forward European cooperation in research and technology?

Let us first cast our minds back to 1980, when Heinz Keller, then Fraunhofer President, was blunt in his criticism of all the previous attempts by the Fraunhofer-Gesellschaft to raise its international profile. He told the Senate that Fraunhofer lacked any firm concept of its international role; and that while it had responded to approaches from abroad, it had not become active itself. An initial attempt to coordinate Fraunhofer’s international activities had seen the establishment of an international office back in 1977. But here, too, this was merely in response to a recommendation by the German Federal Ministry of Education and Research rather than Fraunhofer actually seizing the initiative. Now, however, the Presidential Council resolved to change matters.

Looking back at the 1980s, it is easy to see how tight bureaucratic constraints prevented any powerful engagement on Fraunhofer’s part in Europe’s then developing research market. For a start, the institutes were limited to participation in so-called indirect actions, for which, as a rule, the European Community bore 50 percent of the costs. And given the limited scope for in-house research, there was little or no opportunity to tap base funding. In cost terms, the contribution to EC projects devoured as much as 15 percent of the total funding assigned to the institutes by the operating budget. By comparison, the EC contribution to Fraunhofer’s total revenue was stagnating at a mere five percent. Appeals to the German federal government to come up with subsidiary sources of national funding fell on stony ground. In 1988,

Europe as a knowledge-based economy – Fraunhofer as an engine of innovation

Heinz Riesenhuber, German federal research minister, pointedly reminded Fraunhofer President Max Syrbe that he was at liberty to set his own priorities within the parameters of the existing budget. In the medium term, Fraunhofer hoped to exploit the market for contract research on behalf of companies in neighboring European states. However, this proved all but illusory. Moreover, even those foreign companies with subsidiaries in Germany only accounted for a fraction of Fraunhofer's customer portfolio.

At the time, research bodies in Europe were still largely restricted to their respective country of origin. In seeking to break with this system, and in reaction to the increasingly European character of markets in general, they joined forces to set up the European Association of Contract Research Organisations (EACRO) in 1989. Given the diversity of member organizations, there was some skepticism as to whether a joint representation of interests really made sense. Nevertheless, Fraunhofer was a prime mover in establishing this body, which was intended to advance the Europeanization of the research market, and actively tried to shape this process.

In the course of the 1990s, Fraunhofer increasingly established itself as a global player. The PROFIL program – also known as “Fraunhofer in foreign countries” – was launched in 1995. Aside from Europe, North America and Southeast Asia were identified as key regional markets. By the end of the century, revenues had risen in both regions, though not to an extent that would in any way reflect Fraunhofer's impressive local presence there. They still fell well short of levels in Europe – Fraunhofer's prime focus for internationalizing its business – and would remain so during the first two decades of the 21st century.

The transition from a national to a European research establishment

European heads of state ushered in the new millennium with the Lisbon Agenda and a plan to turn Europe into a knowledge-based economy. In a similar vein, Fraunhofer's Executive Board, writing in the Annual Report of 2000, announced its intention to turn the Fraunhofer-Gesellschaft into a “research organization active on the European stage.” In so doing, the focus would broaden – and, along with it, Fraunhofer's mission. In addition to developing the regional economy and securing the future competitiveness of German industry, Fraunhofer would also be helping to shape the European single market. Yet the “vision of a European Fraunhofer-Gesellschaft” did not extend to the establishment of institutes across Europe. Instead, the idea was to link up with the scientific community across Europe. This would enable Fraunhofer not only to identify business opportunities on a project-by-project basis, but also to develop stable partnerships in the form of joint ventures and thereby help advance the consolidation of the European research sector. With the aim of taking an even more active part in European political discussion, Fraunhofer therefore set up its own Brussels office. In the long term, Fraunhofer's vision was to play a significant role in Europe. For the moment, however, future developments were anything but clear, and the Executive Board resolved to proceed one step at a time.

Nonetheless, it is impressive to see just how rapidly this strategy bore fruit. In 2001, the Fraunhofer-Gesellschaft had business with around 650 European customers, which generated revenues of €29 million. Here, Fraunhofer benefited from two instruments that had been introduced by the sixth EU Research Framework Programme, namely the networks of excellence and integrated projects. By 2004, Fraunhofer had projects in Europe worth a volume of €73 million. Moreover, as one of the prime movers for



research integration on the European level, Fraunhofer also made a valuable contribution to the structured debate with the European Commission on the political framework for research funding. By 2007, Fraunhofer's European revenue had risen to around €98 million, which accounted for the lion's share of total foreign revenue at €125 million. Partnerships had been forged with renowned research bodies such as the University of Cambridge in the UK and the Association des instituts Carnot in France. At the same time, Fraunhofer established affiliates in Austria and Portugal. Fraunhofer Austria cooperated closely with TU Graz and TU Wien in the areas of logistics and production planning, and the Fraunhofer Center in Porto took up research on the use of information and communications technology to assist people with reduced ability.

In the coming years, this rapid growth would continue, with European revenues rising to €145 million in 2011. This made Fraunhofer the most successful German participant in EU funding programs and the second most successful in Europe as a whole. In 2014, revenues rose to a new high of €200 million, due in no small part to the establishment of Fraunhofer affiliates in Sweden (Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik), Italy (Fraunhofer Italia Research Konsortial-GmbH) and the UK (Fraunhofer UK Research Ltd.).

The Fraunhofer 2022 Agenda, drawn up in 2017, places a priority on the further internationalization of Fraunhofer's research operations. The aim here is to generate not only a scientific benefit for the world in general, but also an economic benefit for Germany and Europe. Fraunhofer continues to expand its complex network of collaborative projects, strategic partnerships, project centers abroad and independent Fraunhofer affiliates. At the same time, every effort is made to adapt to the forces of globalization and the rapid pace of scientific and technological change. And Europe

remains the chief focus of Fraunhofer's international activities. The Fraunhofer-Gesellschaft has always been a prime engine of innovation in Europe. At the same time, it continues to work powerfully toward fulfilling its mission of helping to create a unified European research sector and a European knowledge-based economy.

Professor Helmuth Trischler is head of research at the Deutsches Museum. He is also a professor of modern history and the history of technology at LMU Munich (Ludwig-Maximilians-Universität), and the co-director of the Rachel Carson Center for Environment and Society.

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FROM INVENTOR TO VISIONARY FORCE – THE FUTURE ROLE OF THE FRAUNHOFER-GESELLSCHAFT

Prof. Dr. Reimund Neugebauer

Seventy years of Fraunhofer – a success story

Joseph von Fraunhofer was a researcher quite unlike any other before. Despite being self-taught and lacking any formal training, he left a profound impact on the field of optics – one that is still felt today. Moreover, he was adept at translating his research findings into profitable commercial applications – which is why he was chosen as the patron and figurehead of the Fraunhofer-Gesellschaft, which was founded on March 26, 1949 with the declared mission to pursue research solely for the purpose of practical applications. The inaugural meeting took place at the Bavarian Ministry of Economic Affairs. Comprising only a handful of honorary associates, the Fraunhofer-Gesellschaft was originally tasked with raising funds for applied research. These funds were to be passed on to individuals or companies working in this field. By the end of the decade – and following a hefty battle for survival – the Fraunhofer-Gesellschaft had grown to 9 research institutes and 135 employees.

As the demand for applied research grew, so did Fraunhofer. By 1969, it had an annual budget of 33 million deutschmarks and 1200 employees. That year, too, saw the start of institutional funding, which would finally ensure the long-term economic viability of the Fraunhofer-Gesellschaft.

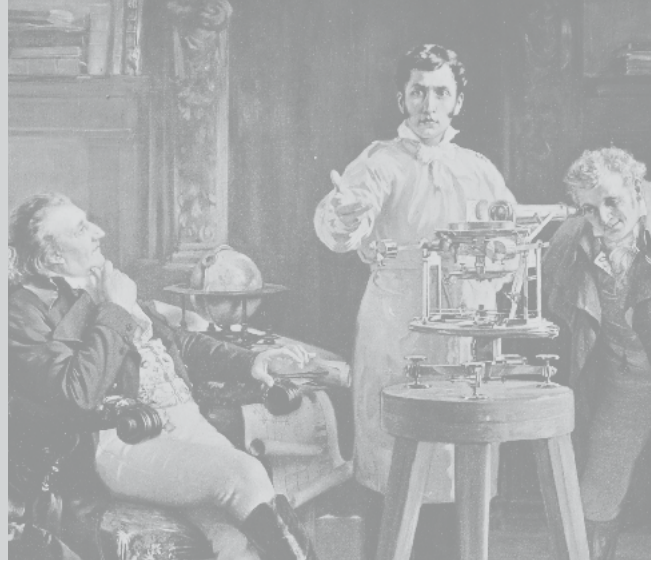
Things further improved in the early 1970s, with the introduction of a new constitution that gave wider powers to the Executive Board and reinforced the role of the Senate. This era also brought an enlarged headquarters, the introduction of codetermination through a new Scientific and Technical Council (STC) and the establishment, in 1972, of a central works council. The introduction of performance-related base funding in 1973 sparked a period of unprecedented growth at Fraunhofer, which had long been regarded as the problem child of the German research family. As a result, Fraunhofer became a leading light of innovation and enjoyed an economic boom. In the 1980s, Fraunhofer implemented a unified communications

network throughout the organization in order to improve the efficiency of its internal operations and of the work in research and administration. With the same goal in mind, Fraunhofer also increased capital expenditure on buildings and equipment.

Fraunhofer adapts its structures and working methods to encourage growth through integration

In the early 1990s, Fraunhofer faced the challenge of incorporating the various research establishments located in the former German Democratic Republic. This task was taken on boldly and with a sense of urgency. In July 1990, the German Council of Science and Humanities was tasked with evaluating the state of non-university research in the GDR. By then, Fraunhofer had already completed an initial assessment and drawn up a plan. Over the coming years, Fraunhofer's incorporation of these new research activities would prove a remarkable success. By the end of that decade, Fraunhofer's budget had risen to one billion deutschmarks. Of that sum, less than ten percent was now earmarked for defense research.

In the first decade of the new millennium, the incorporation of GMD – Forschungszentrum Informationstechnik GmbH and Forschungsgesellschaft für Angewandte Naturwissenschaften (FGAN) – further increased Fraunhofer's size and capabilities. Fraunhofer responded to this expansion with a variety of measures: it intensified its strategy of organizing institutes into groups devoted to specific research areas, it promoted a stronger corporate identity, and it undertook a joint innovation campaign with government aimed at strengthening the German economy. At the same time, the increasingly international character of the research sector led to closer contact to research and industry partners in Europe and beyond. This was a whole new experience for Fraunhofer, which further enhanced its reputation and attracted new customers back home in Germany.



Given this strong growth, Fraunhofer was obliged to continually adapt its own organizational structures. The introduction of new forms of collaboration, such as the Fraunhofer Alliances, helped advance the process of integration within Fraunhofer. Upgrading the position of the research groups and the establishment of a presidential council had a similar effect. At the same time, Fraunhofer's links to the outside research community were strengthened by the creation of innovation clusters and by increased cooperation with research partners from higher education and the Max Planck Society. Sponsorship programs such as Attract were designed to draw outstanding international talent to Fraunhofer and promote creative research. And recruitment drives among students also made a big contribution here.

Science and research are not insulated from social and political change in Germany and Europe. Indeed, the rate at which this change occurs – and the pace of technological progress – has increased in recent years. Applied research is also exposed to this dynamic development and the challenges it brings. It has therefore had to adapt and to devise efficient and sustainable strategies. Fraunhofer has thus developed new forms of cooperation that create interesting and diverse constellations of research and development partners. The aim is to rapidly identify promising and potentially disruptive technological trends, to develop them and thereby acquire system leadership in the relevant technology.

Present position and future mission – quality leads to quantity

Fraunhofer has steadily evolved over the past 70 years, in terms of both its organizational structure and its R&D portfolio. This evolution is manifest not only in Fraunhofer's steadily rising budget, but also in the expanding workforce and growth in the number of Fraunhofer Institutes. This growth reflects the increasingly positive response Fraunhofer

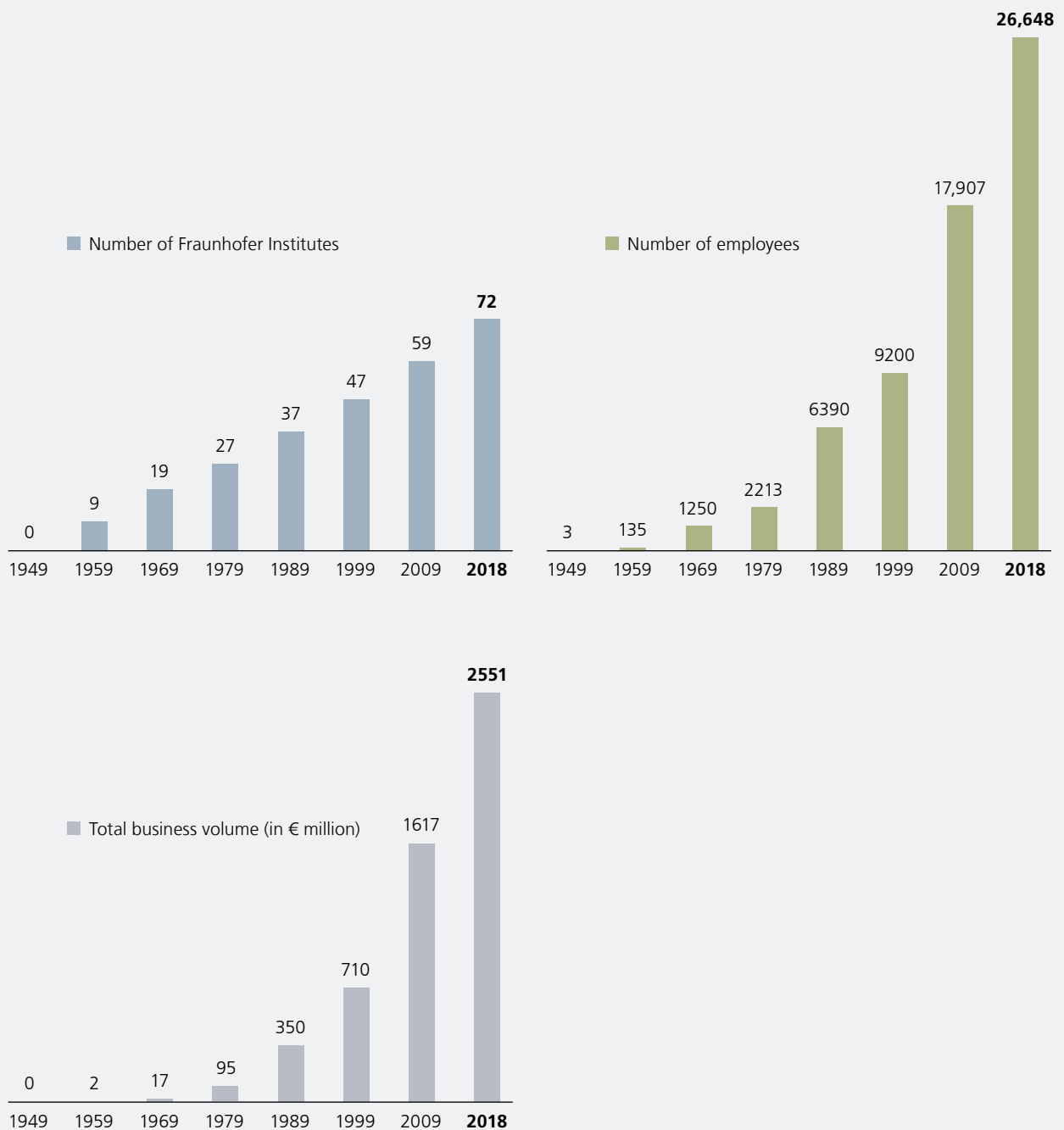
receives from its customers and the strong position Fraunhofer now occupies within the global scientific community. Yet size alone has never been a prime objective of the Fraunhofer-Gesellschaft. In the final analysis, this growth is an index of the quality of the work undertaken at Fraunhofer – in other words, qualitative growth. In turn, this is down to the implementation of modern management practices along with a readiness to take up new R&D topics that are relevant to Germany's standing as an industrial location. In order to be successful, both of these aspects must dovetail with one another. Meanwhile, the so-called Fraunhofer model of performance-related base funding is now a key benchmark for research establishments worldwide.

Fraunhofer plays an important role in Germany's global position as an industrial powerhouse. This requires that we work in close alignment with the aims of both national and international research policies so as to help combat the kind of global challenges that are articulated in the Sustainable Development Goals of the United Nations. In particular, this can be achieved through cooperation with other research establishments. Dynamic networks are built on professional research management and a culture of scientific excellence that is perceived as such by outside players. As a research partner, Fraunhofer is in demand worldwide. Over 20 percent of our revenue from industrial research comes from contracts abroad. Furthermore, of all European research establishments, Fraunhofer is the third-largest contributor to projects in the European Union's Horizon 2020 research and innovation program. We also operate 16 Fraunhofer centers around the world.

Our motto comes from the German industrialist and politician Philip Rosenthal, who once said: "If you think you're somebody, you've already stopped becoming that person." We are in a strong position today, but we will never be complacent. We have initiated developments for the future, which are now being advanced by our internal and external networks. These will enable us to make a key contribution

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Growth at the Fraunhofer-Gesellschaft





to disruptive technologies, such as artificial intelligence, or those technologies needed to implement the shift to a new energy economy.

Technology for tomorrow

Fraunhofer contributes to both national and European initiatives in the field of artificial intelligence. At the same time, we also have a number of major research projects of our own. Researchers at the Fraunhofer Cluster of Excellence Cognitive Internet Technologies are linking sensor systems, data handling and intelligent analysis within a common network. Elsewhere, we are looking to pair self-learning methods with our expert knowledge and process knowledge in order to reach a new level in machine learning and predictive analytics.

One of the major challenges of our age is to limit and control the impact of climate change. The Fraunhofer-Gesellschaft and its customers are working together on innovations that will smooth the transition to greener processes in industry, energy provision and the use of materials. Each of these innovations has the potential to establish new sources of value creation in Germany. To reengineer our energy system, for example, we need new technologies to generate power in a carbon-neutral way. And we also need new technologies that not only allow greater flexibility in how we use this electricity – including for transport and heating – but also ensure it is distributed via smart, secure and resilient grids. By developing new processes for the production of steel or chemicals, we are helping to cut emissions of greenhouse gases in industry. In addition, our innovations are helping to develop new renewable and sustainable raw materials, to close the loop in material and carbon cycles, and to establish new methods of recycling and upcycling.

New networks for a new impact

The Fraunhofer-Gesellschaft was admitted to the joint funding program of federal and state government in 1977. Since then, our mission has been clear, requiring but minimal modifications, and continues to offer good guidance: our goal is to conduct applied research for the benefit of business in Germany and Europe. In Germany's crowded research sector, many players now proclaim to be conducting application-oriented research, so that in the years ahead Fraunhofer will need to further sharpen its profile, highlighting the specific benefits it alone can offer. This is why our vision, as formulated in our guiding principles, now describes a modified goal: our aim is to be an engine of innovation, delivering technological breakthroughs that help solve the challenges of the future. In line with this vision, the objective of the Fraunhofer 2022 Agenda is therefore to "increase the benefit for business and society through excellence and synergy." By limiting the time frame to 2022, the Executive Board and the Presidential Council of the Fraunhofer-Gesellschaft have set an ambitious target and thereby triggered a dynamic process of change. The Fraunhofer 2022 Agenda will implement a series of concrete, certified projects. These will serve to develop and introduce new structures and processes that will enable Fraunhofer – among its own institutes and in collaboration with other research partners – to advance technological trends with a systemic relevance to Germany and Europe. In particular, Fraunhofer is looking at three different constellations: long-term networks with outstanding research partners, strategic partnerships with companies and greater synergies in the cooperation between Fraunhofer Institutes.

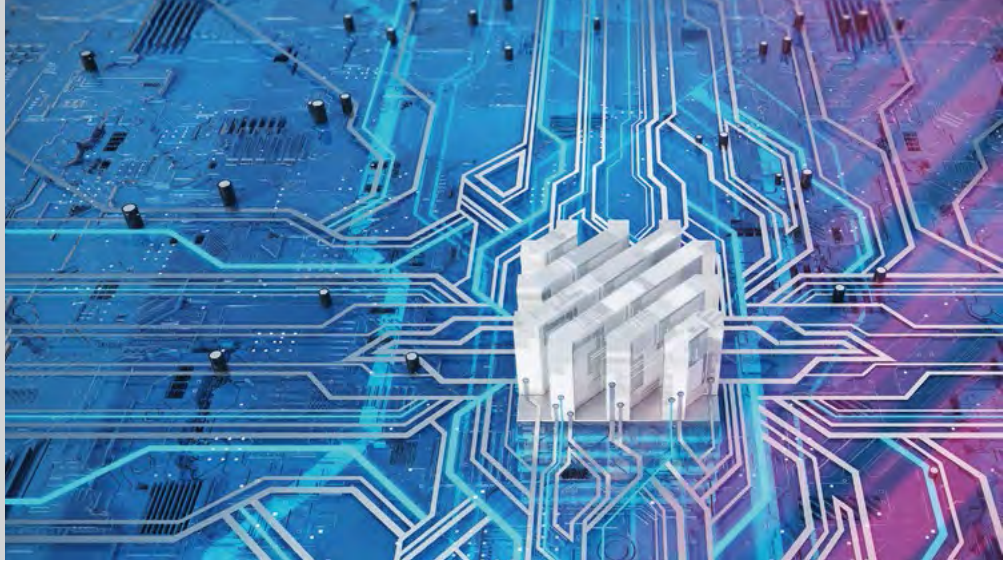
The Fraunhofer model owes its success in particular to the well-established practice of cooperation between our various institutes and nearby universities. For example, it is common practice that the director of a Fraunhofer Institute also holds a professorship at a partner university. Each arrangement is individually adjusted to the precise relationship between

**From inventor to visionary force –
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the institute and the university, so that both sides benefit in equal measure. In adapting strategically to changing requirements in the sphere of higher education, universities now more actively seek third-party funding. This also plays a role in Fraunhofer's ongoing development of these partnerships. This is exemplified by the trial launch of the first High-Performance Centers four years ago. These centers provide a common location for universities and Fraunhofer Institutes to concentrate on a specific research topic. They work together with companies and stakeholders from civil society in order to rapidly transform research into innovations. The partners pool expertise and infrastructure and also run joint training and spin-off programs. An assessment of the 17 High-Performance Centers already in place is currently underway. There are also manifest synergies between Fraunhofer and the university sector in the various clusters of excellence that are funded as part of the Excellence Strategy of the German Federal Ministry of Education and Research (BMBF). To date, Fraunhofer has participated in a total of 15 successful clusters of excellence, together with 16 universities.

Data sovereignty as the basis of collaboration

Each year, Fraunhofer provides contract research for several thousand companies. The volume of these contracts ranges from just a few thousand euros to several millions. In addition to those customers who approach us – and then often return – for a specific solution to a specific problem, we have also set our sights on forging strategic partnerships with companies seeking support with the implementation of new system solutions over the medium and long term. For this purpose, we have tested new cooperation and management models for individual companies and also developed organizational models to tie in companies from different sectors. For example, we have undertaken a strategic initiative together with the International Data Spaces Association that lays the foundations for a trustworthy data economy. This involved the development of an industry-standard reference architecture for new business models that provides companies with a facility to control the transfer of their data, while fully maintaining data sovereignty. This is because we firmly believe that the Chinese and U.S. approaches to data protection and data transfer call for a European alternative that secures the ability of data owners to retain control over access to their data. In collaboration with around 100 companies, use cases are now being implemented on the basis of this prototype reference architecture designed by Fraunhofer. The basic idea will then be translated into domain-specific solutions for the medical sector, for example, or for urban data spaces.



Knowledge transfer with spin-offs

In addition to forging links with established companies, Fraunhofer is also looking to accelerate the establishment of new and agile spin-offs. To this end, we have followed the lead of other research organizations around the world and launched a program to support budding entrepreneurs throughout the spin-off process. If the project is successful, the spin-off founders end up leaving the Fraunhofer-Gesellschaft as employees. As a rule, however, the new venture retains strong links to Fraunhofer, not least because we continue to be a reliable research partner and are often a shareholder in the company. Here, too, the Fraunhofer 2022 Agenda sets an ambitious target. By 2022, Fraunhofer is looking to produce spin-offs at an annual rate of two for every 1000 employees, thereby matching the world's top performer in this sphere – Boston-based Massachusetts Institute of Technology (MIT).

Cooperation with major research organizations

Fraunhofer cooperates with research establishments both at home and abroad. It is only by collaborating with outstanding research partners that we are able to come up with competitive innovations on the global stage. Alongside project-based cooperative ventures, such as European collaboration within EU-funded programs, we are also looking to establish institutional partnerships on a more lasting basis.

Fraunhofer has been cooperating with the major German research establishments on a programmatic level since 2018. This covers not only specific ties between individual Fraunhofer Institutes and local universities, as described above, but also joint programs for project-based collaboration with the Max Planck Society and the Helmholtz Association. In cooperation with the latter, Fraunhofer has also set up a proof-of-concept platform for the production of drugs and medical products and for the accelerated transfer of innovative ideas for medical applications. In a project funded by the BMBF, Fraunhofer has also established the Research Fab Microelectronics Germany (FMD) together with institutes from the Leibniz Association. In the medium term, the partners will also jointly operate this facility. With regard to the future of the national research sector, Fraunhofer would like to see non-university research establishments focus more strongly on their specific mission and unique strengths, so that they can then dovetail smoothly with one another, each bringing along a different area of expertise.

**From inventor to visionary force –
the future role of the Fraunhofer-Gesellschaft**

International cooperation

Fraunhofer has projects with customers or partners in 82 countries around the world. Of all our international partnerships, the eight legally independent international Fraunhofer affiliates represent the most institutionalized form. Of these, five are in Europe, and one each in the U.S., South America and Asia. They function as the legal entities for the Fraunhofer Centers outside Germany, of which there are currently 16. This wide-ranging commitment to the international research community is not an end in itself. Rather, it is a prerequisite if we wish to participate in the production of knowledge worldwide and in the creation of globally competitive innovations. We will therefore continue to make full use of this international network and to deepen our participation in it, supported in this effort by around 500 Fraunhofer employees working abroad. Yet here, too, our goal is less to attain growth in quantitative terms, but rather to intensify the contact to Fraunhofer Institutes back in Germany, with a view to increasing the benefits both to Germany, as a center of innovation, and to the European single market.

Synergy from cooperation between Fraunhofer Institutes

In addition to cooperating with external research establishments, Fraunhofer maintains an internal network of 72 institutes with core expertise in over 300 fields of research. This is an invaluable asset and provides breadth and depth to a research portfolio that makes Fraunhofer unique. No other establishment in the field of applied research has such a wide spectrum of know-how and expertise; and no other body has the uniform governance and management structures required to create such efficient and effective networks within its own organization, as and when required. Our aim is to make even better use of this potential for achieving synergies. In particular, we will strengthen the role of corporate management. In line with this objective, the Executive Board will be responsible on an interdisciplinary level for coordinating all research topics with a systemic relevance. This will also involve the establishment of structures designed to make cooperation between institutes more effective and autonomous. Measures here include the creation of centers of excellence. As quasi-virtual institutes, these will help us, in the case of broad-ranging topics, to rapidly attain a supercritical mass in terms of resources and thereby raise our profile within the research community. Over the past year, these measures have already significantly increased our visibility in areas such as machine learning and decarbonization. Similarly, thanks to coordinated efforts to pool our resources in quantum technology, we are now a recognized player in the field of quantum sensing and quantum communication, where we have already been able to develop initial applications, despite the fact that this area is commonly regarded as still being at the stage of basic research.

70 YEARS OF FRAUNHOFER 70 YEARS OF FUTURE #WHATSNEXT

On the way to becoming a visionary force

On a number of occasions over the past seven decades, the Fraunhofer-Gesellschaft has refocused its research activities and modified its organizational structure in substantial respects, each time in response to changing social, scientific, political and, above all, economic requirements. No other research organization has been required to refocus and regroup to such a degree. Yet our enormous growth in size and significance over this period are testament to the wisdom behind our readiness to adapt and to take on ambitious goals.

As we celebrate our 70th anniversary, it is only natural to ask where Fraunhofer will be in 70 years from now. Given the growing dynamism of the field in which we work, and the increasing pace at which it changes, it is difficult to make precise projections. There are, however, some areas where we can make some general predictions.

A key factor will be the creation of further synergies through increasing integration within our own organization. Here, digitalization is of essential importance. Fraunhofer Digital is part of the Fraunhofer 2022 Agenda. This project aims to give Fraunhofer the most efficient digital administration of any research establishment. As a research organization with core expertise in the generation of data-based knowledge, we are confident that digitalizing our internal administration processes and implementing business intelligence systems to analyze our data will deliver an enormous increase in efficiency, creativity and know-how. This means that we are going to become faster and more effective at producing knowledge. Digitalization will radically increase the degree of cooperation between individual Fraunhofer Institutes, initially on the level of data infrastructure and then of research.

An important step in this direction has been the creation, in recent years, of virtual research bodies such as the Fraunhofer Clusters of Excellence, as mentioned above. Such bodies are flexible and quick to respond to changing circumstances. In years to come, they will increasingly shape the structure of the Fraunhofer-Gesellschaft.

This increasing flexibility will also mean changes to our recruitment policy. It will become more international in order to secure talent from around the world. Moreover, as the demand for well-educated, creative and ambitious people in research rises, the scientific community will have to do more to attract them. Here, too, Fraunhofer has got off to a good start with the launch of the New Work project. The prospect of a fulfilling job is the most convincing argument in making your organization the career choice for people who want to work in research. And what makes this work so satisfying is the opportunity to realize your own ideas and shared visions, ultimately helping to shape the future. This goal and the path leading to it cannot be separated: as an attractive employer for those who want to help create and shape the future, Fraunhofer will be able to consolidate and strengthen its excellent standing within the scientific and business communities and in society at large.

One thing we already know for certain is that the Fraunhofer-Gesellschaft will be a different entity 70 years from now. It will profit from new forms of collaboration but also continue to build upon a highly successful platform of extremely agile, autonomous institutes. Above all, it will continue to pursue the worthwhile and attractive goal of producing research that is of direct benefit to the people.

Prof. Dr. Reimund Neugebauer has been president of the Fraunhofer-Gesellschaft since 2012.

NEW INITIATIVES AND INFRASTRUCTURES

Science faces ever more demanding and complex challenges. The mission and aspiration for the science community is to work with partners in business and society to turn imaginative ideas into innovative solutions and technologies – with its integrity intact and the value created by this transfer benefiting all parties. Researchers, too, have to strike a balance, fulfilling their obligation to their home countries while reaching out across frontiers to partners within the global science community and corporate world. Pressing societal needs are no less challenging for researchers. Education, integration, the shortage of skilled workers, digitalization, economic and ecological sustainability, ethical considerations in the face of new technologies – such concerns occupy scientists today and will continue to do so tomorrow.

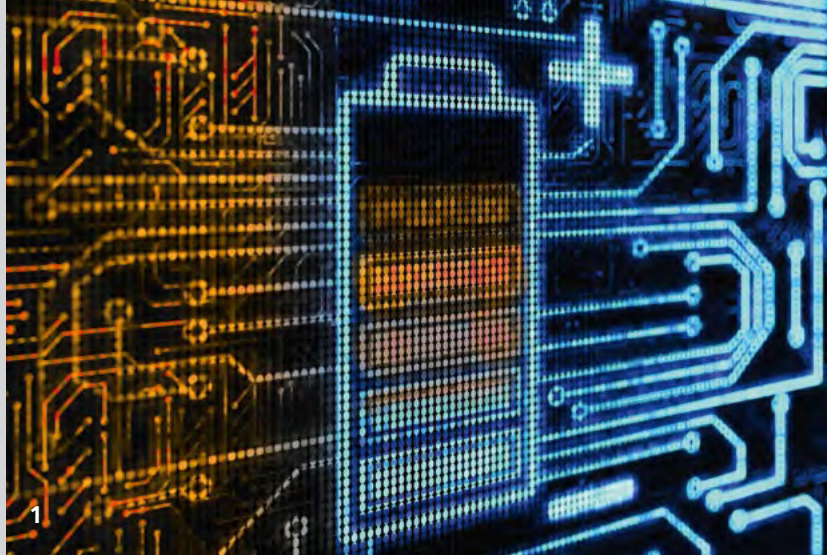
The Fraunhofer 2022 Agenda was adopted in 2017 with these concerns in mind. The organization has been pursuing this agile, cross-institute management policy ever since to prevail in the competition for the best ideas and research outcomes. This approach enables groups of institutes to focus and coordinate their efforts on specific research topics that form part of the Fraunhofer portfolio. Fraunhofer is always adopting new tools to improve internal structures and engaging in new forms of collaboration with partners to maximize synergistic effects.

Fraunhofer Clusters of Excellence **Greater agility with virtual institutes**

Speed is of the essence when it comes to achieving a critical mass of expertise capable of driving forward research in fields of high innovative potential, of relevance both to the local economy and the innovation system as a whole. This is why the Fraunhofer Clusters of Excellence pool assets and resources, bringing together interdisciplinary ad hoc teams from several organizational units to work together in a virtual institute for a limited period of time. Fraunhofer set up four such clusters in 2017:

- Advanced Photon Sources – high-performance laser systems using ultra-short pulses
- Immune-Mediated Diseases CIMD – drugs and therapies for dysfunctions of the immune system
- Programmable Materials – a paradigm change in design where functions are integrated into materials
- Cognitive Internet Technologies – industrial web tech ranging from sensors and intelligent learning processes in data processing to the cloud

Two more clusters joined the fold in 2018:



Fraunhofer Cluster of Excellence Integrated Energy Systems 1

The towering challenge for a world that wants to exit from fossil fuels is how to integrate vast amounts of variable renewable energy sources into the existing power supply system – in an affordable way, with secure supply lines. Engineers are already busy coupling the electricity, heat and transportation sectors, and seeking efficient means of storing energy.

The INES Cluster of Excellence is pursuing three major initiatives to address these technological and economic challenges. One is an energy-modeling platform called EFEU – the Energy Future of Europe. Its purpose is to analyze supply and demand across sectors, which will provide the coordinates for technology roadmaps. The second core initiative involves establishing a software and data hub to plan and manage these infrastructures. Future Energy is a real-world laboratory featuring digitized power and microelectronics components and high-performance computing and communications technology.

The third initiative focuses on the equipment needed to generate, distribute and store large amounts of renewable energy in chemical carriers and products. Much of this effort is directed toward electrolysis, the primary step for most power-to-X technologies. As system analyses and market forecasts suggest, these technologies are well-suited for storing surplus renewable energy and producing green chemical energy carriers for ships, aircraft and the like. The INES cluster is looking to develop efficient methods of electrolysis that bridge the gap between high tech and low costs.

A core consortium comprising the Fraunhofer Institutes for Solar Energy Systems ISE, for Energy Economics and Energy System Technology IEE and for Systems and Innovation Research ISI is addressing the engineering and financial challenges of the global transition to renewables. Fraunhofer

ISE's Professor Hans-Martin Henning and Fraunhofer IEE's Professor Clemens Hoffmann are co-spokesmen of the core consortium's steering committee.

Fraunhofer Cluster of Excellence Circular Plastics Economy

More than half of the plastic collected in Germany ends up in incinerators. Much of the world's plastic waste goes uncollected, accumulating in oceans and other ecosystems. The UN has responded by setting sustainable development goals, one being to ensure responsible production and consumption, and two others to protect ecosystems on land and below water. To achieve these aims, the linear economic system will have to give way to a circular form of resource management. Plastic is indispensable to resource-efficient products because it is so light, but very little of it is repurposed. Conventional recycling methods alone cannot solve the problem with plastic. There are major challenges ahead, particularly for the chemical and plastics industries.

One of the Fraunhofer Clusters of Excellence, Circular Plastics Economy, is the first initiative of its kind to investigate how to redesign the entire plastics value chain along the lines of a circular economy. The idea is to put paid to the practice of burning plastic and spare the environment by recycling materials and resources. This consortium has set out on a ten-year quest to develop new circulating plastics, additives and composites that are recyclable or degradable on demand. It will start with a molecule, work its way up to a prototype and eventually deliver a competitive product. The researchers are making first strides, putting circular design principles into practice to develop a shipping box for online retailers and a car seat for toddlers. These prototypes will come with life-long identification and tracking features.



A core consortium consisting of the Fraunhofer Institutes for Environmental, Safety and Energy Technology UMSICHT, for Material Flow and Logistics IML and for Structural Durability and System Reliability LBF is investigating the circular plastics economy as part of the CIRCONOMY® platform. Other partner institutes are also on board with Professor Eckhard Weidner of Fraunhofer UMSICHT serving as its spokesman.

Lighthouse projects

Inspired solutions for people and markets

The Fraunhofer-Gesellschaft's lighthouse projects are strategic initiatives serving to delineate its portfolio. The research fields in this portfolio intersect with looming social and economic challenges. Several institutes are pooling their skills and exploring technology frontiers to rise to these challenges. In each project, a science consortium comes together for around four years to explore unprecedented approaches aimed to hone Germany and Europe's innovative edge. An in-house competition held every year singles out up to three projects for funding. The members of the Fraunhofer Presidential Council, who include the chairs of all Fraunhofer Groups, select the winning proposals. The Executive Board may also submit a topic every year to support strategic initiatives as it sees fit.

MED²ICIN – the digital patient model

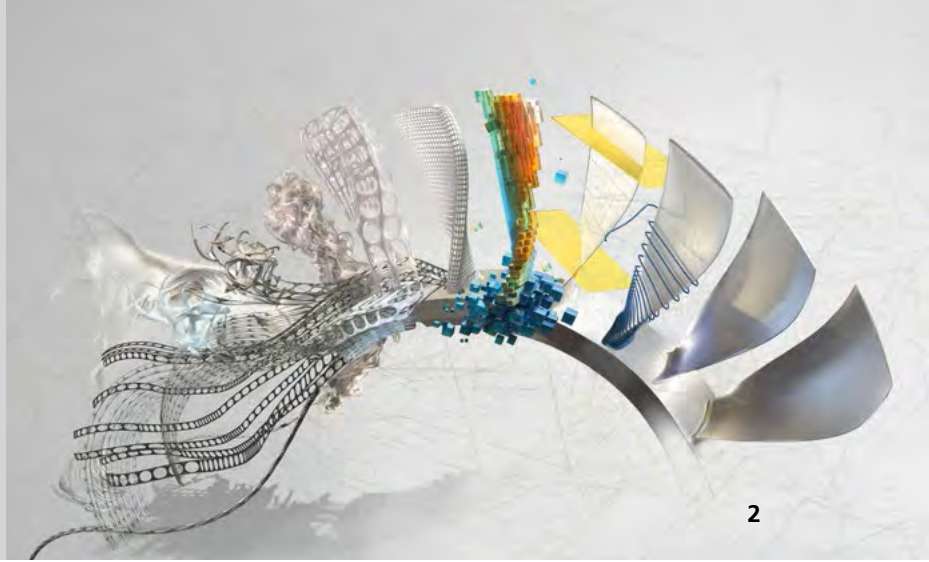
The right method of prevention, diagnosis and therapy at a mere mouse-click – the MED²ICIN consortium is pursuing this vision in an effort to provide better healthcare, with more personalized and cost-effective treatment, to patients.

Seven Fraunhofer Institutes want to redraw the healthcare map to this end, merging yesterday's distributed information

to build tomorrow's digital patient model to arrive at a holistic history that complies with data privacy laws. The consortium envisions a solution that will enable medical personnel to collect, analyze, use and compare all the health-related data of an individual to similar data sets all along the healthcare chain. Emerging molecular data capture technologies and snowballing computing power will enable healthcare professionals to create personalized patient models and supplement these records on the fly with other health and lifestyle indicators. This culminates in a digital profile of each patient. Physicians can compare and contrast this data with cohort knowledge bases, clinical guidelines and other healthcare models. Doctors can analyze these collected and consolidated data troves throughout the healthcare chain to arrive at data-supported decisions, the purpose being to pinpoint the best therapy for the individual patient and provide affordable personalized treatment. Aligned to the needs of different user groups through the application of human-centered interaction design principles, these solutions are easy to handle.

Researchers are developing the first of these digital twins for the healthcare sector to provide evidence-based decision support to physicians treating patients with chronic gastrointestinal inflammation and cancer. The patient retains control over his or her data, deciding if and with whom it will be shared.

The Fraunhofer Institute for Computer Graphics Research IGD is heading up the project. The Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS, for Integrated Circuits IIS, for Molecular Biology and Applied Ecology IME, for Optronics, Systems Technology and Image Exploitation IOSB and for Digital Medicine MEVIS as well as the Fraunhofer Center for International Management and Knowledge Economy IMW are also on board.



COGNAC – Cognitive Agriculture 1

A first order of business on the UN's sustainability agenda is to stabilize the global food situation with eco-friendly agriculture. Eight Fraunhofer Institutes are aiming to do just that in a lighthouse project called Cognitive Agriculture, in which researchers are exploring the fundamentals of producing food and biogenic raw materials in an ultra-efficient way that spares resources and the environment.

They envisage solutions based on digitalizing, automating and electrifying agricultural processes. For example, the Fraunhofer consortium is developing high-performance sensors to be installed in drones and autonomous field robots, which will then provide blanket surveillance of the cultivated fields. The first applications are in the works – one is a gauge to measure soil's nitrogen content, the other a seismic imager to determine soil compaction. This data is vital to farmers' planning and harvest yield, yet they have no way of gathering it. The researchers want to give them the means to collect this data so they can better understand the complex interplay of nature and horticulture and make more informed decisions. In scientific parlance, this ecosystem of networked data and services is referred to as the agricultural data space.

The Fraunhofer Institutes for Factory Operation and Automation IFF, for Ceramic Technologies and Systems IKTS, for Optronics, Systems Technologies and Image Exploitation IOSB, for Manufacturing Engineering and Automation IPA, for Physical Measurement Techniques IPM, for Transportation and Infrastructure Systems IVI as well as for Industrial Mathematics ITWM are taking part in this lighthouse project headed up by the Fraunhofer Institute for Experimental Software Engineering IESE.

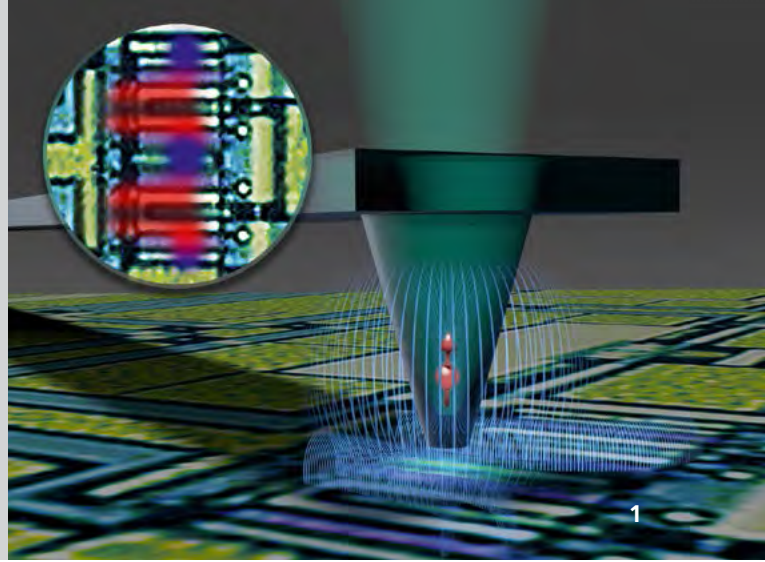
EVOLOPRO – learning, adaptive manufacturing systems 2

The goal of the EVOLOPRO lighthouse project is to develop a "biological manufacturing system" that evolves using mechanisms much like those of living organisms to adapt, quickly and autonomously, to new demands and changing environmental conditions. The system learns from manufacturing flaws, so a faulty product is a valuable lesson rather than just another candidate for the scrap heap.

Although new algorithms rooted in biology feature prominently in EVOLOPRO, it also entails a digital twin that interacts with a digital environment. Borrowing from the Darwinian theory of the survival of the fittest, this is a virtual contest where the discrepancies between the perfect product and the actual outcome are analyzed and evaluated in the digital realm.

To validate the computed results, the researchers plan to develop demonstrators for three pilot applications – a single turbomachinery component, several components assembled in an optical system and several components interacting in a toolmaking application.

This lighthouse project is a concerted effort of the Fraunhofer Institute for Production Technology IPT, the project lead, and the Fraunhofer Institutes for Mechanics of Materials IWM, for Applied Optics and Precision Engineering IOF, for Material and Beam Technology IWS, for Machine Tools and Forming Technology IWU, for Applied Information Technology FIT and for Algorithms and Scientific Computing SCAI.



Combustion Engines for Tomorrow's Mobility – New Drive Systems, Fuels and AI

Despite the growing trend toward electrification, the internal combustion engine will remain the dominant form of mobility for many years to come. With its unrivaled efficiency, it is the propulsion system of choice for ships and aircraft, and still prevails in commercial vehicles, trucks and passenger cars as well. Combustion motors drive portable power tools such as chainsaws and stationary machines such as generators and combined heat and power plants.

A lighthouse project undertaken at the behest of the Fraunhofer Executive Board, which goes by the name of “Combustion Engines for Tomorrow’s Mobility – New Drive Systems, Fuels and AI,” is a national initiative to create an integrated transportation system that unifies economic and ecological goals. Reducing pollutant emissions, fuel consumption and carbon emissions is a daunting challenge. The scientists engaged in this project aim to rise to it by building on earlier research to develop three new ways of boosting efficiency and cutting pollutant emissions – lean-burn combustion, catalytic evaporation (CatVap), and residual heat and energy recovery.

Keen to improve the methods used to produce renewable fuels and shrink the internal combustion engine’s carbon footprint, they are advancing the state of the art in oxymethylene ether production, alcohol condensation and thermo-chemical reforming (TCR®). Fraunhofer has the technologies, infrastructure and expertise needed to conduct lifecycle assessments and analyze economic and technical factors. Another subproject aims to produce a cognitive model of the internal combustion engine in order to optimize its performance. The idea is for an engine control unit to capture and analyze more information about events in the combustion chamber. Then, with the benefit of reinforcement learning, it can better control these processes. The Fraunhofer

Institutes for Chemical Technology ICT, for Solar Energy Systems ISE and for Environmental, Safety and Energy Technology UMSICHT are taking part in this initiative led by the Fraunhofer Institute for Optronics, Systems Technology and Image Exploitation IOSB.

Quantum magnetometry – precision sensors at the atomic level 1

Magnetometers lack the spatial resolution and sensitivity needed to detect very small magnetic fields. In the years ahead, the Fraunhofer QMag consortium intends to demonstrate two newly designed quantum magnetometers that make use of quantum sensors. For one, its scientists want to use nitrogen-vacancy centers in diamonds as tiny magnetic probes, turning a single atomic system into a highly sensitive sensor that operates at room temperature. For the other demonstrator, they are striving to develop a low-cost sensor based on legacy magnetometer prototypes. The researchers plan to integrate nuclear magnetic resonance (NMR) detectors and optically pumped alkaline magnetometers into this system. Currently available magnetometers lack the spatial resolution and sensitivity needed to detect very small magnetic fields. In the years ahead, the Fraunhofer QMag consortium intends to demonstrate two newly designed quantum magnetometers that make use of quantum sensors. For one, its scientists aim to use nitrogen-vacancy centers in diamonds as tiny magnetic probes in an imaging scanning probe magnetometer, turning a single atomic system into a highly sensitive sensor that operates at room temperature. The other measuring method takes advantage of the migration of alkali atoms in a magnetic field to create optically pumped alkali magnetometers, or OPAMs for short. The goal is to develop full-fledged, cost-effective measuring systems for specific applications based on legacy prototypes of these magnetometers.

The two measuring methods' sensitivity and spatial resolution are complementary, so they can address different applications. These novel quantum magnetometers could serve to non-destructively test and optimize microelectronic and nano-electronic components or even to visualize a single bit's worth of memory. They could also bring an unprecedented level of precision to applications in non-contact material testing and chemical process analysis.

The Fraunhofer Institute for Applied Solid State Physics IAF is spearheading this project. Its other stakeholders are the Fraunhofer Institutes for Physical Measurement Techniques IPM, for Mechanics of Materials IWM, for Microengineering and Microsystems IMM, for Integrated Systems and Device Technology IISB, and the Fraunhofer Centre for Applied Photonics CAP, a joint venture of Fraunhofer IAF and the University of Strathclyde in Glasgow, Scotland.

Max Planck Schools

A new way of pooling excellence

A nationwide initiative of universities, research organizations and the German Federal Ministry of Education and Research (BMBF), Max Planck Schools promote a new brand of graduate education in Germany. Their mission is to pool research excellence across the country, strengthen the German science community and boost its profile abroad to attract outstanding young researchers from all over the world. Three schools stood out among the competition and started offering programs in 2018:

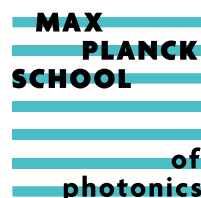
- the Max Planck School of Photonics
- the Max Planck School of Cognition
- the Max Planck School Matter to Life

Backed by 21 universities and 31 non-university research institutes, these select schools consolidate scientific excellence from the far corners of Germany, each bringing the best together in one field of innovative research.

The Max Planck School of Photonics (MPSP)

The Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena heads up the Max Planck School of Photonics. Germany is a global leader in photonics, a dynamically evolving field of scientific discovery. Some of the seven Nobel Prizes awarded in this field since 2000 acknowledged advances in optical communications, digital photography and energy-efficient, ecofriendly light sources that triggered transformative changes in the economy and society. Photonics is also a catalyst for innovation-driven industries such as information technology, aerospace engineering and industrial manufacturing.

"MPSP marks a new level of networking in the photonics community. It pushes the frontiers on cutting-edge topics such as attosecond physics and quantum photonics. The network showcases the photonics community's ability to bridge the borders of disciplines and cross institutional barriers, enabling it to tackle grand challenges in science," says Professor Andreas Tünnermann, founding director of the Max Planck School of Photonics, director of Fraunhofer IOF and of the Institute for Applied Physics at Friedrich Schiller University Jena.



High-Performance Centers

Infrastructure to fast-track research transfer

A High-Performance Center is a place for Fraunhofer to join forces with universities, colleges, non-university research institutions and enterprises to investigate specific topics and conduct application-minded research. These partners convene at that one place to pursue the common goal of boosting the economic impact and social benefits of research and development. Knowledge transfer is usually a sequential, linear process. With this joint effort, the transfer from the lab to the real world takes on parallel, multidirectional trajectories.

The development of the network of High-Performance Centers in Germany as a vector for technology transfer is one of the key items on the Fraunhofer 2022 Agenda. Transfer roadmaps chart the course for knowledge transfer. There are six paths for a transfer to take – contract research, licensing, spin-offs, continuing education, minds and careers, and citizen science. These maps provide a route that takes the particulars of the given field of research and the strengths of the given location into account.

Dortmund's Enterprise Labs stand as an example of this close collaboration between research institutions and business enterprises. Their scientists team up with industry experts from the likes of Deutsche Telekom and Boehringer Ingelheim, working together to drive the advance of solutions in logistics and IT. Products such as a low-cost tracker go to show how this kind of collaboration can improve processes in manufacturing, logistics and aviation.

High-Performance Centers also offer services tailored to technology-driven small and medium-sized enterprises (SMEs). For example, the High-Performance Center Translational Biomedical Engineering in Hannover is helping the medical device sector, which consists mainly of SMEs, to deal with the challenges of new regulatory procedures by providing advanced training on developing and obtaining approvals for medical products.

Another effective form of knowledge transfer is the start-ups born of and around these High-Performance Centers. The Berlin Center for Digital Transformation is a case in point. A technology partner of the de:hub IoT platform and thus a part of the German Federal Ministry of Economics and Energy's nationwide initiative called Digitalization Hubs in Germany, it provides the environment and infrastructure high-tech start-ups need to thrive. Its cutting-edge technological support benefits Fraunhofer spin-offs and other start-ups.

Fraunhofer set up 17 High-Performance Centers in 11 German states during the seed round of funding between 2015 and 2017. By the end of 2018, ten of these centers had received a favorable evaluation, making them eligible for a second round of funding, in which Fraunhofer and the host states will provide the funds to carry them through the end of 2020, on condition that industrial partners contribute 40 percent of the required sum.



An initiative for more efficient transfer of research DFG and Fraunhofer launch a trilateral program

In October 2018, the Deutsche Forschungsgemeinschaft (DFG) and the Fraunhofer-Gesellschaft launched a program for trilateral projects with industry, the aim being to fast-track the transfer of basic research and boost its benefits to business and society.

This pilot initiative steps up the collaboration among universities, non-university research institutions and business enterprises to steer basic research findings down the right path toward successful applications. The stakeholders' methodical approach to knowledge-sharing gives companies the opportunity to participate in the development of new technologies at an early stage and by doing so create added value for their business. This is particularly beneficial for SMEs lacking in-house R&D departments.

The transfer program builds on the latest findings of DFG-funded university projects, which Fraunhofer and industry partners then develop further into prototypes or demonstrators as part of a streamlined, collaborative effort. Fraunhofer Institutes serve as intermediaries, liaising between universities and application partners. This approach enables pre-competitive research to be conducted in an academic setting while also building bridges to industry that will be essential when the time comes to commercialize the results. Fraunhofer spearheads the effort to exploit the results of these projects with business partners; universities receive a fixed percentage of the proceeds in return.

Fraunhofer and DFG will each provide €3 million in funding per call for proposals. Industry partners are expected to contribute in kind by devoting €3 million worth of research effort to the collaborative program. This scheme can provide funding for at least five projects every time a call for proposals goes out. The selection process for the first round of proposals will take place in the second quarter of 2019.

A new conference series FUTURAS IN RES 1

"Biological Transformation in Manufacturing" was the focus topic of the international science conference FUTURAS IN RES initiated by Fraunhofer. This Berlin event was such a rousing success that Fraunhofer is now determined to establish an annual series of conferences under this label. The focus topic for 2019 is "What's the IQ of AI?"

PROJECTS AND RESULTS 2018

HEALTH AND ENVIRONMENT

T cells for a new cancer therapy

CAR T-cell therapy is a cancer immunotherapy. It recruits the patient's innate immune cells – that is, T cells – to fight certain types of cancer, particularly of the hematopoietic system. Isolated from the patient's blood and genetically reprogrammed in a pharmaceutical cleanroom lab, T cells are able to seek out cancer cells using their chimeric antigen receptor, and then destroy them. Reinfused into the patient after preparatory chemotherapy, the reprogrammed cells proliferate in the patient's body, triggering an immune response. The gene therapy product, registered under the trade name Kymriah®, was authorized for use in the European Union by the European Medicines Agency (EMA) in August 2018. First approved for use in the U.S. by the FDA in 2017, this novel therapy based on chimeric antigen receptor T cells or CAR-T cells for short, is now also available in Europe. Novartis shared the underlying technology with the Fraunhofer Institute for Cell Therapy and Immunology IZI in 2015. Fraunhofer IZI then obtained a license to manufacture the product in compliance with Section 13 of the German Medicines Act (AMG) and has been producing CAR T cells since 2016 for Novartis' clinical trials in Europe. The Novartis Group continues to pursue its global development, supply-chain and manufacturing strategy with this decision to make Fraunhofer IZI one of its main manufacturing facilities in Europe.



1

Hugo Geiger Prize

Big data for Alzheimer's research

Researchers the world over are vigorously investigating Alzheimer's disease. Coordinating and analyzing their findings is a towering challenge given the scale of these efforts. Indian bioinformatician Dr. Alpha Tom Kodamullil's dissertation, a meta-study, examined peer-reviewed publications in leading journals such as *Alzheimer's & Dementia*. Conducting big data analyses to assess innovation strategies in the pharmaceutical industry, Kodamullil showed that Alzheimer's research has merely focused on a limited subset of potential disease mechanisms. Her publications were a contributing factor when the European Commission tasked the Fraunhofer Institute for Algorithms and Scientific Computing SCAI with coordinating an €18-million lighthouse project named AETIONOMY. Part of the Innovative Medicines Initiative (IMI), this public-private partnership's brief is to investigate diseases of great social import. Alzheimer's disease is one. A century after Alois Alzheimer's discovery, this form of dementia has yet to be fathomed. Alpha Tom Kodamullil set up a collaboration with Cohen Veterans Bioscience (CV Bio), a war veterans' organization based in Cambridge, U.S.A., to expand the Bioinformatics business unit at Fraunhofer SCAI. She was awarded the 2018 Hugo Geiger Prize in recognition of her work.

Joseph von Fraunhofer Prize

Safer surgery around the world 1

The liver and its complex vascular system present a daunting challenge for surgeons. Researchers at the Fraunhofer Institute for Digital Medicine MEVIS teamed up with surgeons, radiologists and industry partners to develop image processing algorithms and software to support the preparations for liver surgery. They present 3D anatomical views and analyze risks using mathematical models to provide more precise guidance for surgeons planning incisions for tumor resections, living-donor liver transplants and the like. Determining the best place for an incision in this meshwork of tissue is not easy for surgeons seeking to excise centrally located malignancies or multiple primary cancers. Fraunhofer MEVIS developed special liver analysis algorithms to assess radiological data, generate a detailed 3D model of the organ's anatomy and calculate the risks of prospective incision placements and lines. All this goes to improve the odds of a successful procedure. Collectively known as MEVIS analysis, these advanced algorithms are in use worldwide. Dr. Andrea Schenk, Dr. Stephan Zidowitz and Alexander Köhn received the 2018 Joseph von Fraunhofer Prize for this work, on behalf of the interdisciplinary consortium and development team.



A prosthetic hand with a sense of touch

A consortium of institutes pursuing a Fraunhofer lighthouse project called Theranostic Implants aims to combine therapeutic and diagnostic functions in a single medical device. These devices have to be biocompatible and operate reliably for many years, despite the tendency of cells to proliferate in the warm, humid environment of the human body. One of the demonstrators produced by the research team led by the Fraunhofer Institute for Biomedical Engineering IBMT is a myoelectric hand prosthetic controller. Difficult and inefficient to use, currently available prosthetic hands are not particularly wearer-friendly. Perhaps their greatest drawback is that they fail to convey a sense of what things feel like. This is why the scientists set out to develop a myoelectric prosthetic hand controller with sensory feedback. It controls the prosthetic fingers by measuring changes in the residual arm muscles' bioelectric potential, or in nerves that have been selectively transplanted from the pectoral muscles. The prosthetic hand's ability to provide sensory feedback to the wearer is a breakthrough achievement. Its fingers are fitted with pressure sensors for this purpose. Surgeons also implant a stimulator, attaching filament electrodes as thin as a hair directly to the nerve. The researchers developed a special electronic application-specific integrated circuit (ASIC) to be implanted for signal acquisition, signal conditioning and stimulation.

The prosthetic hand was not the only achievement born of this lighthouse project. It also produced a sensor implant for controlling blood circulation and a smart prosthetic hip joint. When the team of scientists from 12 Fraunhofer Institutes headed up by Fraunhofer IBMT selected demonstrators for this project, they focused on aspects of patient care that account for a large share of the costs borne by German health insurers.

Concrete structures made of renewables 1

TÜV Rheinland, an inspection and certification service, says that one in every two bridges in Germany is decaying, compromising the country's road network. This is one of the reasons why engineers are increasingly turning to textile-reinforced concrete containing non-corroding carbon fibers, glass fibers or plastic fabric as a substitute for traditional steel-reinforced concrete. A case in point is an Istanbul bridge across the Bosphorus Strait that links Europe and Asia. Its pylons are clad with a textile-reinforced concrete with a much longer service life. Yavuz Sultan Selim Bridge has been open for traffic since 2016.

A Braunschweig-based research team has now succeeded in reinforcing concrete with ecofriendly, natural flax fibers. This greener option shrinks the material's carbon footprint and cuts manufacturing costs. By adding strands of polymer fiber to the flax, the researchers can create a hybrid fabric tailored to any given component's requirements. The experts at Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI's Application Center for Wood Fiber Research HOFZET® use a double-rapier loom with a Jacquard attachment to weave this material mix. They can produce innovative lightweight composite fabrics with complex structures tailored to the given application using conventional and sustainable materials. Natural resins enhance the structural density to ensure a long service life. A prototype of a vegetable-fiber-reinforced concrete bridge was on show at an international trade fair for architecture, materials and systems in Munich in early 2019.



Biofuel refinery in a container 2

Humankind will probably need gasoline to fuel internal combustion engines in conventional cars and hybrids for decades to come. Biofuel would certainly be the more sustainable option. Twelve research partners led by the Fraunhofer Institute for Microengineering and Microsystems IMM joined forces in an EU project called BIOGO to develop a prototype plant to convert forestry waste and tree bark into biofuel. A 40-foot container holds all the reactors and other processing equipment needed to produce it – pyrolysis oil, synthesis gas and synthetic gasoline. The consortium even managed to accomplish this without the precious metals and rare earths that the catalysts for these processes usually require. Instead, the researchers developed resource-conserving nano catalysts based on catalytically active substances. The partners involved in this project aim to advance the state of the art by building a prototype that can produce 1000 liters of eco-fuel a day. And the chemical industry could find other uses for these containers, for example, to convert waste materials such as carbon dioxide into methane to be piped into the natural gas grid. Operating the container near a wind or solar power plant could further reduce the carbon footprint.

A diamond to better detect cardiovascular diseases

Cardiovascular diseases are the most common cause of death worldwide. In a bid to improve patients' chances of recovery, medical researchers are looking for better ways of understanding and treating metabolic processes. Today's examination devices are complex and expensive, but fail to provide high-definition images. Quantum technology, in contrast, holds great potential for improving magnetic resonance imaging (MRI). The Fraunhofer Institute for Applied Solid State Physics IAF has teamed up with partners in industry and science in the MetaboliQs project to develop a novel mobile diamond polarizer for MRI scanners that operates at room temperature. This new imager is 160 times as efficient and 40 times as fast as the conventional option. Studying the metabolic processes of heart tissue at a molecular level to obtain more accurate results for more precise diagnoses is now a realistic prospect. The MetaboliQs project is funded as part of Horizon 2020, the European Union Framework Programme for Research and Innovation.



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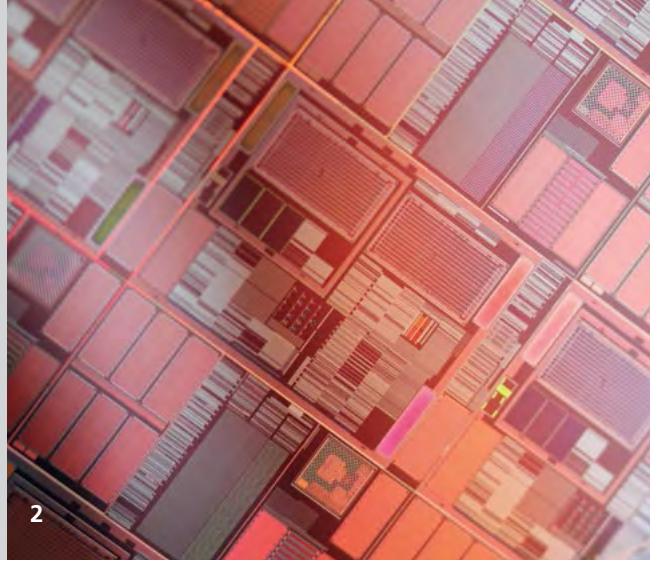
COMMUNICATION AND KNOWLEDGE

Stifterverband Science Prize

Free-form optics – small but splendid 1

Light is a universal medium for conveying energy in (data) communication, manufacturing, power generation and optics. However, the potential of conventional spherical and aspherical optical systems is all but tapped out. Free-form optics, with their folded beam paths, enable engineers to give shape to surface profiles with new functions as they see fit. They require fewer lenses, so they are conducive to very compact designs that deliver improved image quality despite their smaller footprints. The team led by Dr. Ramona Eberhardt at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF partnered with a host of stakeholders to create a comprehensive technology platform for optical free-form systems with exceedingly compact designs. Cutting and polishing optical glass with painstaking precision, coating complex surfaces – this industry and science consortium tackled some towering technical challenges to achieve this remarkable feat.

The first demonstrators show this new technology's functions and performance potential. It can serve as infrared optics for rescue forces, as powerful yet compact specialized optics for space telescopes, in driver assistance systems and in environmental engineers' earth and weather observation applications. A project funded by the German Federal Ministry of Education and Research (BMBF), it is helping to buttress the optics industry in Thuringia. The Stifterverband Science Prize was awarded to Dr. Eberhardt and her team in acknowledgment of their achievements.



A spectrometer for quantum effects

Highly miniaturized electronic circuits already exhibit quantum mechanical effects. To better understand these effects, scientists need photoelectron spectrometers to determine how electrons' energy is distributed during photoionization. Seeking to advance the state of the art in quantum technology, a research team comprised of staff from the Fraunhofer Institutes for Applied Optics and Precision Engineering IOF and for Laser Technology ILT and from the Max Planck Institute of Quantum Optics developed a new spectrometer capable of operating in the megahertz range. These photonics experts revolutionized photoelectron spectrometry in the space of two years. The prototype runs at 18 megahertz, eclipsing today's standard kilohertz range. The number of pulses bombarding the atomic bonds in target materials has increased a thousand-fold with this advance. Measurements that once took five hours, pushing samples' stability and beam source parameters to their limits, can now be carried out in a mere ten seconds.

The science team greatly improved three main components of the spectrometer. They increased a titanium sapphire laser's pulse energy from 300 microwatts to 110 watts, and then demonstrated for the first time that pulses may be shortened by widening and compressing the laser beam spectrum on a solid object. This short-pulse laser light now needs more energy to knock electrons out of the underlying object. To do this, the team developed a super-elevation resonator serving to emit high-energy XUV attosecond pulses in a gas jet. A specially developed mirror with a tiny hole directs these pulses, ensuring nothing else enters the spectrometer's sample chamber. The PowerQuant project is part of the cooperation program between Fraunhofer and the Max Planck Society.

Energy-saving tech for new microchips 2

The Internet of Things, self-driving cars, advancing mobile communications – new IC technologies are very much in demand in all these growth markets. Market researchers estimate that the number of connected devices will increase to somewhere between 20 and 50 billion worldwide by 2020. The Fraunhofer Institute for Photonic Microsystems IPMS and Dresden-based chip manufacturer Globalfoundries are developing innovative materials, processes and components for the next generation of semiconductors, based on fully depleted silicon-on-insulator technology, or FD-SOI for short. These chips' complex circuit design offers many advantages, including higher energy- and cost-efficiency, more power and faster switching times. FD-SOI chips have a buried oxide layer beneath a thin silicon film. This reduces the connective layer's thickness, leakage and process-related variations in chip quality. Fraunhofer IPMS aims to expand its cleanroom to around 900 square meters and equip it with new systems as part of the project. The German Federal Ministry of Education and Research (BMBF) is supporting the Fraunhofer IPMS with funding earmarked for the Research Fab Microelectronics Germany (FMD).



Hugo Geiger Prize

A fully automated pipeline for 3D data 1

Dr. Max Limper of the Fraunhofer Institute for Computer Graphics Research IGD developed the new SRC data standard and POP buffers, a 3D data streaming method, for his thesis. Dr. Limper, a computer scientist, packed these innovations into InstantUV, a new software for 3D data programmed to create a compact version of the input data that looks much like the original. It can convert a richly detailed 3D scan consisting of 10 million triangles with a file size of 500 MB into a far smaller yet almost identical copy comprising just 10,000 polygons in a 5 MB file.

The new software is to serve in 3D online presentations as well as for virtual reality (VR) and augmented reality (AR) applications. Fraunhofer IGD has licensed InstantUV to various companies and institutions worldwide. It marks a milestone advance for the new graphics language transmission format known as glTF 2.0. Facebook, the world's biggest social network, Microsoft applications such as Paint3D and PowerPoint in Windows 10, and all browser-based 3D engines support this standard format. Dr. Limper took top honors for his work, winning the 2018 Hugo Geiger Prize.



2

The last mile for the industrial Internet of Things 2

The Internet of Things is taking shape with information technology connecting countless objects. The Fraunhofer Institute for Integrated Circuits IIS has created one of the first standardized communication solutions for applications in the industrial Internet of Things (IIoT) – a wireless, software-based transmission technology called MIOTY®. The institute's scientists developed a procedure called "telegram splitting" to facilitate the energy-efficient, robust and reliable transmission of sensor data between individual objects and entire data sets over long distances. Telegram splitting has since been integrated into the MIOTY® technology, patented and licensed. With the benefit of this solution, hundreds of thousands of sensors or IIoT mobile devices can send up to 1.5 million data packets a day to a single collection point without any transmission loss, even in areas with poor or no cell phone coverage.

This transmission technology is an early complier – it already satisfies the TS 103357 standard for energy-efficient networks over long distances published by the European Telecommunications Standards Institute (ETSI) in mid-2018. Compliance with this standard is one of the prerequisites for ensuring the smooth interaction of different services. Behr Technologies Inc. (BTI) was set up in Canada to commercialize and license MIOTY® technology worldwide. With this technology, engineers can bridge that last mile of communication to enable end-to-end digitalization even for challenging industrial applications where adverse environmental conditions prevail. The oil, gas, mining and other industries have deployed MIOTY® in pilot projects.

Futurology comes alive with 3D mixed reality

Bringing factories, houses and entire cities to life, the Elbedome 3D mixed reality lab treats people to a walkthrough experience, rendering even very large virtual objects in lifesize scale. Located at the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg, this research lab reopened in 2018 after several years of extensive modernization. With a height of 4 meters, a diameter of 16 and over 450 square meters of projection area, it is one of the largest and most advanced facilities for industrial virtual and mixed reality applications worldwide. Equipped with floor projectors and the latest stereoscopic simulation technology, the system renders virtual objects holographically to treat groups of up to 30 people to an enveloping interactive experience. Users can dive in and work in the immersive virtual worlds conjured in this lab. Its researchers are collaborating with partners in science and business to develop tomorrow's workstations and manufacturing systems, and support elaborate construction projects. They are investigating robot work cells, production and processing plants and even entire industrial parks.

The sheer size of the virtual reality lab and the realism of its holographic images convey the impression that users really are immersed in a virtual world. They can assess the status of their plans, expedite decision-making, and support qualification, communication and marketing efforts. And all this is done in real time, in a realistic environment and before taking any action in the real world with nothing but digital data to go by. Blending different types of data in this VR centrifuge, all the participating experts can engage in interdisciplinary collaboration and share information with everyone at the same time. This speeds up planning and development efforts while delivering more robust results and driving down costs.



PROTECTION AND SECURITY

Joseph von Fraunhofer Prize XXL computed tomography 1

With just a few hundred kiloelectron volts of radiation power to draw on, conventional X-ray computed tomography is suitable only for scanning smaller, easily penetrated objects. Michael Salamon, Nils Reims and Dr. Michael Böhnelt and their team from the Fraunhofer Institute for Integrated Circuits IIS have changed that with a remarkable advance. Their brand of XXL computed tomography can x-ray objects far larger than earlier systems have been able to scan. To accomplish this feat, the researchers paired a nine-megaelectron-volt linear accelerator with a large X-ray line camera. A heavy-duty turntable rotates the objects to deliver a richly detailed, high-contrast 3D image. This scanner is opening windows of opportunity for a host of industries. Automakers could use it to probe the damage of crash tests, security and customs authorities to x-ray freight containers, and historians and archaeologists to look into artifacts. The three researchers were awarded the 2018 Joseph von Fraunhofer Prize for their achievements.



Earth-bound space junk 2

It was another one of those sinking moments in the early morning hours of April 2, 2018, when space debris came crashing down to Earth at 2.15 a.m. central European time. The eight-and-a-half metric-ton Tiangong-1, a Chinese space station, plunged into the Earth's atmosphere over the south Pacific. Experts believe much of the space laboratory could have withstood the heat as it entered the lower reaches of the atmosphere, with many small pieces raining down on the planet's surface. Ground control had lost contact to Tiangong-1 in early 2016, so a controlled re-entry over the sea was not an option. The station had been slowly but steadily approaching Earth ever since it went rogue. Events like this prompt space agencies around the world to closely monitor debris' descent to predict the time and place of re-entry. Scientists at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR near Bonn observed Tiangong-1 for weeks using TIRA, a space "Tracking and Imaging Radar" equipped with a 34-meter parabolic antenna. This combination of imaging and tracking radar serves to detect and observe objects with remarkable precision regardless of distance, local weather conditions and time of day. Fraunhofer FHR supported the German Space Situational Awareness Center by tracking Tiangong-1's orbital trajectory until it crashed in April 2018. The European Space Agency (ESA) and its European Space Operations Centre (ESOC) in Darmstadt also tasked the Fraunhofer Institute to investigate Tiangong-1's self-spin. This rotational action influences the aerodynamic force acting on the cross-sectional area of the space station and thus the time of re-entry. In the end, the atmosphere incinerated most of the Chinese space station, with the residual debris plummeting into the Pacific Ocean.

Quantum technology to guard against eavesdropping

These days, quantum encryption is quick to come to mind when engineers think about ways to protect data communication. The Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, teamed up with 16 partners to ensure attempts to intercept data communication no longer go undetected. This international consortium is developing miniaturized optical integration solutions to shoehorn the entire system onto a single chip. In project UNIQORN, part of the EU's Quantum Flagship initiative, researchers are applying the laws of quantum mechanics to tap sources and distribute keys. All this goes to deliver an affordable encryption option for the mass market. Fraunhofer HHI's PolyBoard technology provides the underpinning for this innovative integrated system-on-a-chip. This tech allows engineers to populate the chip with integrated optical components and functions, and link them to photonic integrated circuits without having to accept compromises that might limit the micro-optical components' performance. PolyBoard has already served to develop miniaturized optical components for telecom and data-com applications, and for micro-optical chips used in analytics and sensor technology.



Protective film to deter hardware attacks 1

Hackers are devising ever more sophisticated ploys to gain access to sensitive data in embedded systems. The Fraunhofer Institutes for Applied and Integrated Security AISEC, for Microelectronic Circuits and Systems IMS and for Microsystems and Solid State Technologies EMFT pooled their skills in an in-house project to provide deep security that would protect chips against attacks at the system level. Their innovative solution consists of a tamper-proof foil with an electrically conductive grid structure wrapped around the entire circuit board. The idea behind this approach is that each foil exhibits unique production-related variations much like a fingerprint. These are then surveyed to define a physical unclonable function (PUF) for use as a cryptographic key. The recipient can only decrypt the data if the foil is fully intact. The system automatically deletes critical information such as cryptographic keys if the grid sustains damage during operation or someone tampers with the integrated measuring circuits.



Nano probes on the hunt for bacteria

Potable water is often in scarce supply in the wake of earthquakes, floods, droughts and other natural disasters. When shortages loom, water quality analysis methods have to be reliable and fast. Researchers engaged in a project called AquaNANO have developed a detection module serving to analyze nanosamples of drinking water for contaminants. Scientists, businesses and public infrastructure companies teamed up in this three-year joint research project headed up by the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and funded by the German Federal Ministry of Education and Research (BMBF).

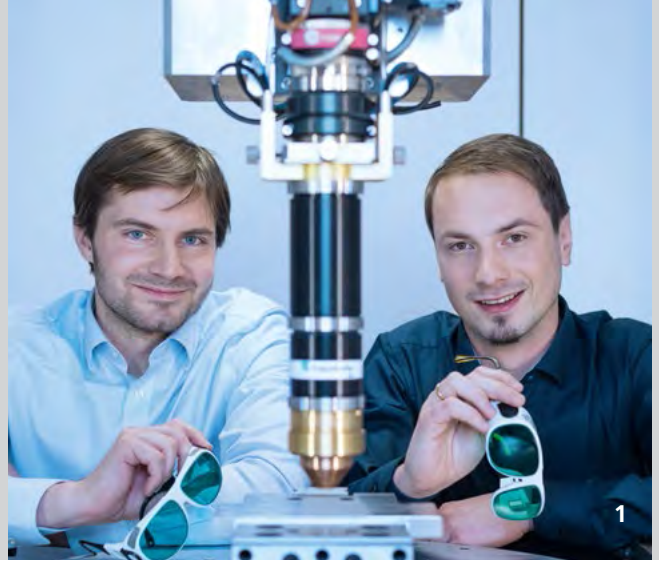
The partners came up with a demonstrator that delivers results within an hour. Conventional water testing methods take up to 24 hours. The demonstrator works with nanoparticles coated with special antibodies to detect pathogens. Introduced into the water sample, these tiny coated particles behave like probes. Bacterial pathogens and toxins in the water bind to these magnetic nanoprobables, which are then relatively easy to spot using special detection compartments. This fast, reliable way of identifying harmful substances enables responders to take quick measures to protect the populace. With the benefit of AquaNANO, aid organizations such as the THW (German federal agency for technical relief) will have a powerful portable tool to test larger drinking water reservoirs for potential biological contaminants. This detection module was presented at the German Federal Ministry of Education and Research's Civil Security Innovation Forum held in June 2018.

Safer urban centers 2

In late 2018, the German city of Mannheim deployed cognitive software to upgrade its video surveillance and better protect citizens at several crime hotspots. Developed by the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB, this smart video evaluation system enables security forces to intervene at an earlier turn, while better protecting personal rights and data.

Cameras installed by the city and police authorities feed images into Fraunhofer IOSB's cognitive software. It detects suspect patterns of behavior that could be the precursor to acts of violence, and alerts the police officers tasked with monitoring video surveillance cameras. This expedites decision-making, helping officers to decide if they need to dispatch emergency responders to the scene of the incident. Anything in the surveillance footage that has no bearing on police matters can be pixelated or blurred to render it anonymous.

Baden-Württemberg law has approved the use of automated analysis of surveillance camera images since late 2017 with the caveat that people may only be identified if their behavior suggests the intent to commit a criminal offence. Mannheim was the first city to take this opportunity. Although scientists developed the assistance system in the lab, they will continue to train it using real-world scenarios to improve its ability to detect telltale patterns of movement.



MOBILITY AND TRANSPORTATION

Joseph von Fraunhofer Prize

3D printing for better aircraft turbines 1

Jet engines have to take a lot of punishment, especially when they are made to run hot and cold during takeoff and landing. The Fraunhofer Institute for Material and Beam Technology IWS has developed innovative technologies and manufacturing methods to enhance the stability of engine parts exposed to high temperatures. Teaming up with Dr. Dan Roth-Fagaraseanu of Rolls-Royce, Fraunhofer researchers Professor Frank Brückner and Mirko Riede found a way to produce finely wrought microstructures in an additive manufacturing process. These microstructures today serve as the standard material for constructing innovative thermal barrier coatings (TBCs). A metallic, oxidation-resistant adhesion promoter layer and a ceramic insulating layer are clamped together to make TBCs for installation in the section of the engine exposed to hot gas. This layered system helps improve the engine's design by extending the coatings' service life. This is one of the measures to cut kerosene consumption and pollutant emissions, and save nearly US\$ 3 million a year per aircraft. Long-haul aircraft such as the Airbus A350-1000 have been taking to the skies with these new engines since February 2018. The 2018 Joseph von Fraunhofer Prize went to these researchers in recognition of their achievement.



Hugo Geiger Prize

A laser to go

Dr. Christoph Werner from the Fraunhofer Institute for Physical Measurement Techniques IPM laid the foundation for a cost-effective new laser light source so very compact that it could well end up in smartphones. It would enable practically anyone to conduct laser tests that were once the sole province of specialized laboratories. As part of his thesis work, the researcher collaborated with Fraunhofer IPM to develop a novel laser light source with adjustable output wavelengths and compact dimensions. The microsystems engineer devoted six years to his dissertation, going as far to build the equipment needed to put his theory into practice.

Based on a whispering-gallery resonator, Dr. Werner's laser source uses an unusual light feedback-based approach to stabilize the light waves inside the resonator. He also explored unfamiliar territory for the resonator, using a ring mounted on a piezoelectric actuator rather than a disk. It responds to applied voltage by expanding. This method of tuning the resonator by thermal means rather than by changing its geometry accelerates the process by a factor of 100,000. It is also more independent of wavelengths. His thesis research also yielded a happy by-product, a new crystal structuring process. Fraunhofer IPM is now negotiating a licensing agreement with one of the international market leaders in this field. Dr. Christoph Werner won the 2018 Hugo Geiger Prize for his research.

Pallets get smart 2

The Internet of Things is making inroads into logistics with bright prospects for wide-scale adoption. Deutsche Telekom, the Fraunhofer Institute for Material Flow and Logistics IML and EPAL, the European Pallet Association, have been trialing an application with 500 smart pallets. A new low-cost tracker with a battery life of two years enhances the quality of logistics services and helps keep data secure in the Internet of Things.

Around 30 percent of all global deliveries fail to reach their destination on time. Cargo theft costs companies billions in damages. This robust, waterproof tracker is a remedy for those pains. Its built-in sensors can also track other parameters, for example, to ensure packages ship in compliance with regulations and the forwarding agent maintains the required cooling temperatures in transit. The device uses the global 3GPP standard and Telekom's NarrowBand IoT machine connectivity. The low-cost tracker outperforms GPS-based technologies with low power consumption and good building penetration. This innovation comes courtesy of the Telekom Open IoT Labs run jointly by Fraunhofer IML and Telekom. It is not the first invention to emerge from these labs; they also produced an IoT service button. This smart retrofit for logistics companies, factories, workshops, construction sites and hospitals serves to provide custom IoT solutions, for example, to reorder spare parts or call for containers to be collected.



Phoning via drone

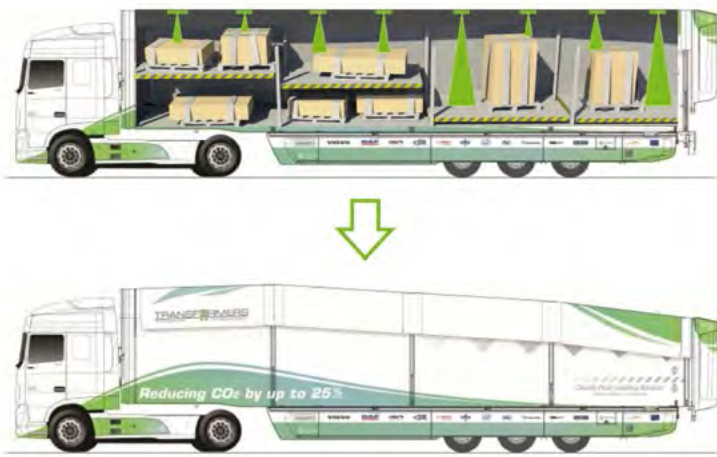
Drones may be tasked to do many helpful things, for example, to reduce delivery traffic on the road or scout out hazardous situations for rescue forces en route. A controller steers the aerial vehicle by issuing commands; the drone reports back with data on its position, altitude and battery status. Conventional communication options such as radio and cellular data channels have their limitations and may not always be reliable. Mobile networks' voice channels are more stable and robust. Cellular networks provide almost universal coverage and don't require additional infrastructure, thus keeping a lid on added costs.

Researchers at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, use the cellular network's voice link to convert outgoing control commands to the drone into audio signals. A module on the drone converts the signals back into commands. The principle is much like that of old-school modem connections. The drone has a standing order to call back as soon as possible in the event of an interrupted connection. The airborne device relays its position and height in real time so it can be tracked via an online map service, for example. The drone may also be fitted with sensors enabling it to independently dodge unexpected obstacles.

Safe signals for autonomous vehicles 1

Communication is critical to autonomous vehicles – they cannot be controlled without it. A reliable channel for exchanging information between the vehicle and its surroundings is imperative for connected and automated driving. A software program is now available to monitor and predict the quality of service provided by wireless communication.

One constant of wireless communication is that its quality varies, especially in environments as dynamic as traffic on public roads. The monitoring system developed by the Fraunhofer Institute for Embedded Systems and Communication Technologies ESK continuously tracks communication between vehicles and key environmental parameters such as topographical features. It monitors the communication flow of all de facto and official wireless standards such as 802.11p and LTE, and will do the same for upcoming 5G. Machine learning algorithms enable it to predict the quality over the next few seconds and, in some situations, even minutes in advance. Fraunhofer ESK's solution offers wide scope for developers of automated driving applications, enabling them to implement functions such as platooning and lane merging assistants.

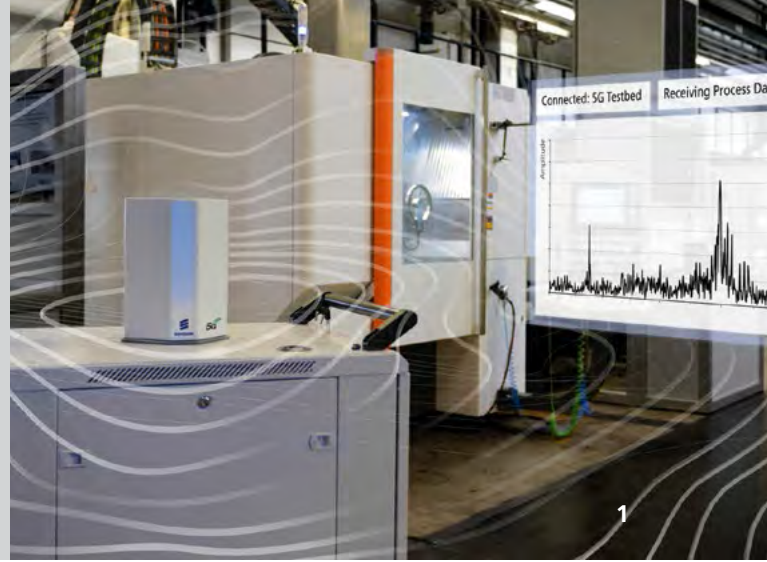


2

A truck that adapts to its load 2

Scientists engaged in TRANSFORMERS, an EU research project, have developed solutions that do justice to its subtitle, Configurable and Adaptable Trucks and Trailers for Optimal Transport. A trailer with an adaptable structure and a hybrid drive slashes fuel consumption by as much as 25 percent, particularly when hauling palletized freight. The Fraunhofer Institute for Structural Durability and System Reliability LBF, a member of the R&D consortium, came up with a sensor system to measure the volume of the load and a battery housing to power the trailer's electric auxiliary drive. These remarkable savings are explained by three innovations: The truck's structure and load-carrying capacity adapt to the given mission. An electric auxiliary drive built into the semi-trailer activates on demand. And optimized aerodynamics reduce drag all around.

The Fraunhofer Institute for Transportation and Infrastructure Systems IVI spearheaded the effort to develop this innovative hybrid-on-demand drive. It pairs a conventionally powered tractor with an electrically driven trailer. This is a win on three fronts: Lower fuel costs per metric ton and kilometer benefit the operator. Reduced CO₂ emissions are good for the environment. And road traffic flows more smoothly with less congestion uphill and in cities. The EU made it official in August 2018 – the TRANSFORMERS project is a success story.

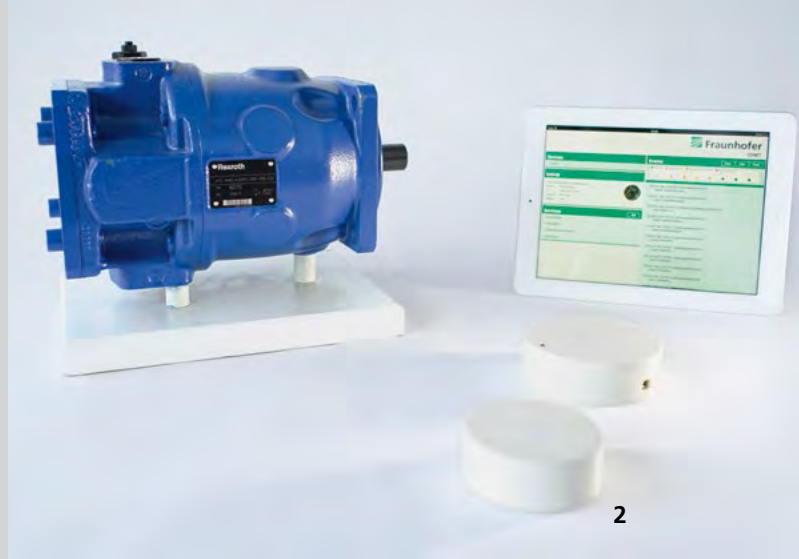


PRODUCTION AND SERVICES

Flawless manufacturing with 5G 1

The new 5G mobile communication standard supports direct, real-time wireless monitoring to enable early fault diagnosis in industrial manufacturing. The Fraunhofer Institute for Production Technology IPT in Aachen and Ericsson set up a unique testing environment for 5G applications at the International Center for Networked, Adaptive Production (ICNAP) to monitor aircraft components during the manufacturing process.

The blisks, or integrally bladed rotors, used in modern aero engine turbines and compressors are complex components consisting of the rotor disk and a variable number of airfoils or blades, milled as a single piece. They can cost as much as €200,000 to make. Individual blades may vibrate when they are machined, causing defects that require elaborate rectification. This is why modern-day machines and plants are equipped with sensors to constantly monitor the manufacturing process. However, errors are still assessed locally and with some latency. That issue may be redressed by combining state-of-the-art sensors with the 5G mobile communication standard's fast data transmission capabilities. Sensors attached to the component transmit blisks' vibration spectra to an evaluation unit via 5G with no more than a millisecond's latency. The manufacturing process may be adjusted the moment vibrations approach a critical level. Engineers can also use the collected data to create a digital twin of the blisk, which can then serve to do things like validate simulated results.



Wood waste – fodder for power plants

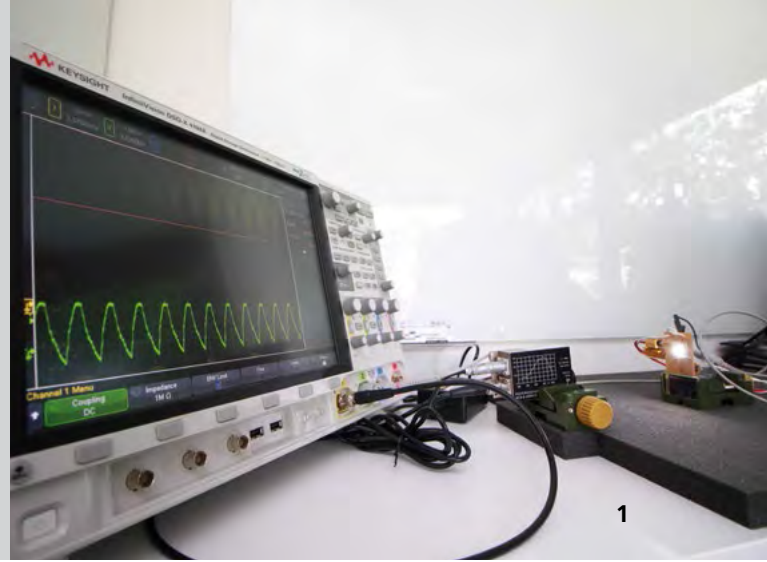
Scientists working on the EU SteamBio project led by the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have been investigating the use of wood as substitute for oil and natural gas, both as fuel and as a feedstock for platform chemicals. The first step involves treating low-grade wood chips with a thermal process called torrefaction. These researchers improved this widely used technology by retaining the biomass's residual moisture and the vaporized products of torrefaction as superheated steam in the process chamber to serve as the process medium. Volatile substances are valued products of torrefaction. They may be processed to obtain chemicals that serve as feedstock for a wide range of industrial products.

This technology's benefits do not end there. Torrefied biomass is lighter and water-repellent. This reduces shipping costs and effort. The process also increases the fuel's specific calorific value. Ground to a highly reactive powder, it can feed coal-fired power plants in its pure form or when mixed with coal dust. Fraunhofer IGB and a metalworking/mechanical engineering company jointly set up a pilot plant fired with beechwood biomass. Another plant has been up and running in Spain since January 2018, where the partners in this project torrefy pine, oak and beech wood alongside vine cuttings and the waste from olive oil production.

Audio sampling to maintain pumps 2

Predictive maintenance can help prevent damage, minimize downtime and avoid unexpected costs. As it turns out, the noise made by a running machine can actually be a source of information. Experts at the Fraunhofer Institute for Digital Media Technology IDMT in Oldenburg have found a way to exploit these audio signals for predictive maintenance purposes. They equipped axial piston pumps with smart battery-powered sensors to this end. Installed in construction and agricultural machines or industrial conveyor belts, these pumps convert mechanical force into hydraulic force. The sensors sample the airborne noise made by pumps, process and evaluate it with machine learning algorithms, and transmit the data to a digital evaluation unit via a wireless link. This method of early fault analysis can point to issues with bearings, hydraulics and other parts. It enables engineers to take corrective action before the powertrain or hydraulics incur costly damage.

The Fraunhofer experts at Oldenburg contributed their unique skills, providing the technology to simulate the human ear's capabilities and incorporating it into this solution. Drawing on environmental audio samples to take ambient noise into account, this application factors irrelevant noise out of the equation. Training with machine learning methods improves its performance. With a signal processor built into the local sensor, the system is affordable and its data stays secure. It may be upgraded with anything from Internet connectivity to remote maintenance capability. Industry customers benefit from a cost-effective, scalable Industrie 4.0 solution that keeps data secure and helps reduce downtime. The German Federal Ministry of Education and Research (BMBF) funds efforts to develop audio sensor systems with industrial partners in the ACME 4.0 project.



Substantiating credentials with blockchain

Blockchain can do more than back up deals done with the cryptocurrency bitcoin. Cryptographic technologies serve to secure many transactions, for example, in the Internet of Things, for complicated contractual matters such as intellectual property, and in supervisory and regulatory processes – particularly those involving distributed, autonomous organizations. The Blockchain Lab at the Fraunhofer Institute for Applied Information Technology FIT has developed an application for the continuing education and job market. Designed to authenticate the origin of certificates, it provides, verifies and archives documents substantiating academic and professional credentials. In this way, it can be ensured that certificates are not tampered with after they have been registered.

Accredited bodies for the certification of persons, including universities, chambers of industry and commerce, certification services such as the German TÜV and other issuing agencies can take part. To do so, they have to register issued documents' digital fingerprint in the blockchain, stating the certificate's expiration date. The owner of the document can then refer to this archived registration to substantiate its provenance. Being able to prove the authenticity of a certificate is a key economic factor in the era of online job applications, lifelong learning and a global employment market. The Fraunhofer Academy and the Fraunhofer Institute for Applied and Integrated Security AISEC helped develop Blockchain for Education, a community platform that is open to educational institutions and businesses.

Machines that communicate via light 1

How efficient would Production 4.0 be if the many networked devices and products were connected in a reliable way? The bandwidth, coverage and device count limitations of legacy radio technology certainly affect manufacturing. That could change if the people, machines and products on shop floors start communicating via light pulses. The range of possibilities is far greater with a light spectrum that exceeds the available radio spectrum by a factor of 4800. The Fraunhofer Institute of Optronics, System Technologies and Image Exploitation IOSB is heading up a project to this end launched in late 2018 and funded by the German Federal Ministry of Economics and Energy. Its researchers are striving toward light-based data transmission robust enough to shrug off interference and other adverse conditions. Stray light, shady spots, fast-moving objects, large shop floors: these are just a few of the many challenges facing the ten industry partners, mainly SMEs, who are exploring light-enabled data communication in this project. This is why the researchers first set out to analyze these challenges. They will then develop various technologies to solve these problems. In the interests of energy efficiency, all will be based on legacy light-source infrastructure. The Ostwestfalen-Lippe University of Applied Sciences and Deutsche Forschungsgesellschaft für Automatisierung und Mikroelektronik e.V. are part of this consortium.



GDPR, an opportunity in waiting 2

The EU General Data Protection Regulation, or GDPR, is more than merely a catalog of fines. Its purview extends beyond data protection to afford companies and public authorities the opportunity to optimize their business processes and IT infrastructures. All this goes to enhance efficiency, competitiveness and security. With these aims in mind, the Fraunhofer Institute for Open Communication Systems FOKUS is collaborating with the Fraunhofer Academy to provide training and consulting services, for instance in the Cyber Security Laboratory. A case in point: Researchers at the Digital Public Services division have been supporting the Berlin Senate's ISBJ program (integrated software for youth services) for ten years now, keeping the platform's IT architecture management up to date. Evolving architectural specifications have a major impact on the selection and rollout of standard software and on in-house efforts to develop specialized IT. The brief for IT architecture management is to assure the quality of interfaces to various services, support information security and data protection efforts, and monitor approvals issued by the Berlin Commissioner for Data Protection and Freedom of Information.

The GDPR demands two things of software – data protection by design and data protection by default. Few software products satisfy both. Fraunhofer FOKUS advises companies, helping them to develop and assess software that complies with data protection regulations. To accomplish this goal, its researchers devised a test based on their experience with proprietary software and best development practices. It determines whether developers programmed the software with data protection in mind.

A digital revolution in sheet metalworking

The Fraunhofer Institute for Machine Tools and Forming Technology IWU has devised a manufacturing system with a working miniature press and a digital twin to prove that end-to-end digitalization is a viable prospect in sheet metalworking. Called Forming 4.0, it can deep-draw, cut and bend components. The idea behind a digital upgrade is to create value by adding features to monitor the process, machine, tool and material, and perform a final optical inspection of the component. This feature set can help make the manufacturing process more robust, increase machine availability, extend service life and accelerate tool setup time.

With force and position sensors, an inline material test, and optical inspection capability built in, the machine is able to monitor itself and the components it produces. This inline material test examines the semi-finished product on the fly before the machine deep-draws or cuts the component to size. This way, the machine identifies material-related defects in the component so they can be remedied at an early turn. It also saves on material – what would have once ended up on a scrap heap is now reused to manufacture intact parts. Sensor data is not the only source of information for assessing component integrity. An inspection performed at the press's runout conveyor provides additional insight. It examines the sheet metal components' geometry optically, checking every single component for defects. Integral to the Forming 4.0 system, this optical inspection not only assesses the component's quality, it also provides big-picture indications as to the condition of the overall manufacturing system.



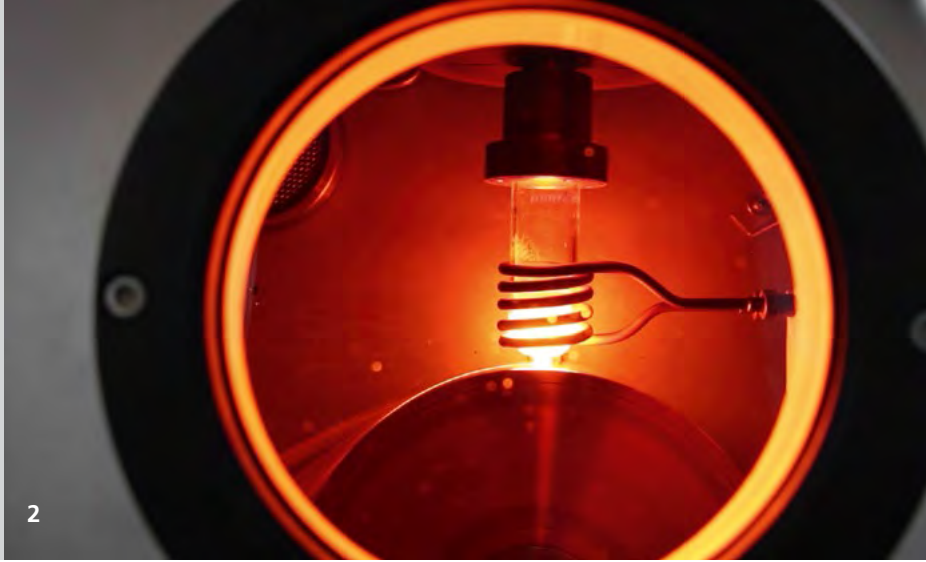
ENERGY AND RAW MATERIALS

Green power for more sustainable chemicals manufacturing 1

Electricity generated from renewable sources can be used to produce basic chemicals such as hydrogen peroxide, ethylene and alcohols. A consortium led by the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT has shown that innovative sector coupling in the power grid and novel electrochemical processes can add a greener touch to the chemical industry.

Germany's exit from fossil fuels is not only opening the door to new ways of generating electricity with lower carbon emissions. It is also the gateway to sector coupling, a new approach to powering factories. This research team developed a demonstrator to electrochemically convert carbon dioxide into basic chemicals for ethylene manufacturing and make short-chain alcohols such as methanol via high-pressure electrolysis. Long-chain alcohols serve to manufacture fuel, cosmetics and laundry detergents. Seeking to make these alcohols with carbon dioxide and water, the researchers combined legacy processes and developed new technologies to speed up these processes.

The team achieved its goal of conserving resources, energy and capital with a new electrochemical method of making hydrogen peroxide. This on-demand manufacturing process not only consumes less energy and solvents; it also reduces logistics and storage costs. Alongside these innovative processes, the scientists' four-year research effort to generate electricity from renewable resources also yielded powerful tools such as a new membrane for partitioned electrochemical cells, system analysis tools, market models and sustainability assessments to support business decisions.



Going easy on rare earths 2

Rare earth metals are among the world's most strategically prized resources. They figure prominently in the permanent magnets that no electric motor or wind turbine can do without. Rare earth mining leaves vast tracts of land polluted with toxic residue. More than 90 percent of the world's deposits are in China, so the supply chain is hardly a bastion of stability. Eight Fraunhofer Institutes headed up by the Fraunhofer Institute for Microstructure of Materials and Systems IMWS set out to find ways of conserving rare earths. They succeeded by developing improved manufacturing and recycling processes and substitution strategies to exploit these resources more efficiently. These experts found that demand for dysprosium and neodymium could be reduced to a fifth of today's level by making the most of savings potential and finding substitutes for certain applications. And they built a small electric drive and a large traction motor to prove it.

Opportunities to recycle and conserve these resources abound when designing motors and manufacturing magnets. For example, a motor that runs at a lower operating temperature requires less dysprosium. A combination of injection molding and sintering with a material mix reduces the rejection rate and the need for reworking. A new recycling process first pulverizes old permanent magnets with hydrogen, and then recasts and sinters the powder to reconstitute the material. These recycled magnets perform almost as well as a new product (96 percent). The researchers also applied high-throughput methods to find materials and develop alloys to replace some or all of the dysprosium and neodymium in magnets.

Powerful batteries

Germany's exit from fossil fuels and emergent electric vehicles are driving demand for high-performance batteries that can turn volatile natural resources into a constant source of energy and extend vehicles' range. The German Federal Ministry of Education and Research (BMBF) has responded with several initiatives to promote battery research. They provide incentives encouraging manufacturers to build plants in Germany and make durable, safe batteries that can stand up to global competition. Determined to drive the development of a new generation of batteries, scientists from twelve German universities and research institutions joined forces in ProZell, the BMBF's battery cell manufacturing cluster, to improve the manufacturing process and its effect on battery cell properties and production costs.

A consortium led by the Fraunhofer Institute for Ceramic Technologies and Systems IKTS has set itself the aim of boosting the energy storage density of lithium-ion batteries and thereby extending the range of electric vehicles. In particular, the Fraunhofer Institute for Silicon Technology ISIT and other partners are investigating electrode structures and ecofriendly dry-coating processes. The Fraunhofer Institutes for Manufacturing Engineering and Automation IPA and for Industrial Mathematics ITWM are taking part in other projects pursued by the cluster, exploring cost- and energy-efficient ways of dry-coating electrodes and improving electrolyte absorption to accelerate the manufacturing process.



Roof-ripened vegetables 1

A project is underway in Oberhausen to provide a sustainable supply of fresh food to the region. Called the Altmarktgarten, this building-integrated agricultural initiative is unlike any other in Germany to date. A job center newly built on the Altmarkt square in downtown Oberhausen opened for business in late 2018. Its rooftop vegetable garden will start growing food for the region in spring of 2019. This urban horticulture is based on inFARMING®, a concept developed at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. The idea is to link farming systems with building infrastructure. In this case, the systems divert gray water and rainwater flows and CO₂ produced by the job center's in-building systems to provide water and energy for the rooftop vegetable garden. The Altmarktgarten encompasses more than 1000 square meters of cultivated area, with a section of it devoted to research. This is where engineers study and develop technical systems for urban agriculture. The Altmarktgarten is a lighthouse initiative of the German government's National Urban Development Projects.



A self-sufficient floating house 2

Up and running since early 2019, a floating house on Lake Bergheide in the Lusatian Lake District serves as a research and demonstration platform for a largely self-sufficient energy supply. Called autartec®, this R&D initiative taps local sources to furnish power and water to communities on the banks of waterways and to floating buildings. It uses conventional photovoltaic modules and thin-film photovoltaic elements to harvest energy and provide shade. The building's shell, which is fitted with lithium-ion batteries, can store up to 50 kWh – enough to supply the house with electricity for five days without having to draw on any other source of energy. The researchers also developed a plant to furnish water and treat domestic waste water. Parts of this plant are built into the house's floats. It uses no synthetic chemicals.

Much of the building's overall energy efficiency is down to its shell. Designed to retain heat well, autartec® roof and wall cladding also mimics natural cooling effects. A salt hydrate stores heat captured from the chimney, later releasing it back into the building. A green façade and a cooling ceiling help keep the room temperature comfortable. A combination of heat accumulators and a seawater heat pump keep the indoor climate cozy in winter. All components are connected and managed by smart controllers. Fifteen partners are taking part in the German Ministry of Education and Research's Innovative Regional Growth Core project, including the Fraunhofer Institutes for Transportation and Infrastructure Systems IVI and for Ceramic Technologies and Systems IKTS.

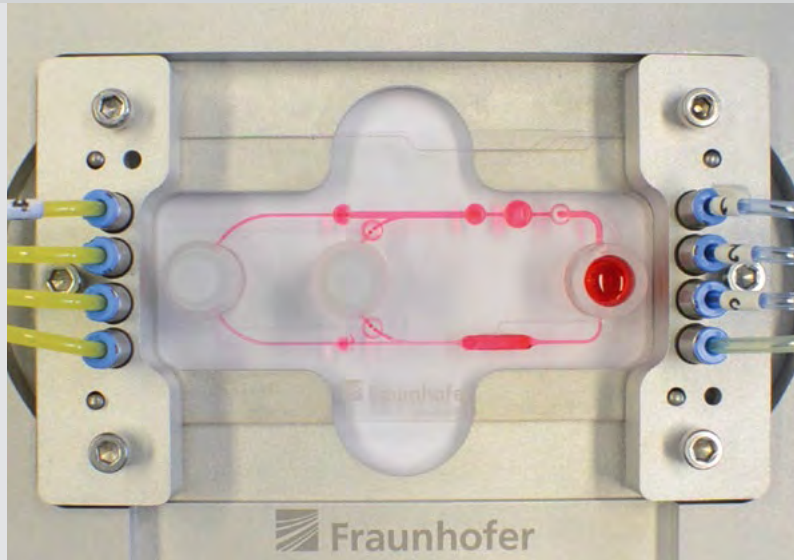
Shrinking the steel industry's footprint

If global warming is to be contained, everyone will have to pitch in and reduce emissions of greenhouse gases such as CO₂. This presents a great technical and economic challenge for heavy industries such as steelmaking. Salzgitter AG is doing its part with SALCOS®, a modular project aimed at gradually dialing back CO₂ emissions in Germany and Europe's steel industries. Fraunhofer was on board to provide science-based support.

The traditional coal-fired blast furnaces that forge steel from iron ore produce large amounts of CO₂. Steelmakers could reduce these emissions by 95 percent if they first switch to natural gas and then to hydrogen sourced from renewables. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS and Salzgitter AG are taking part in the MACOR feasibility study funded by the German Federal Ministry of Education and Research (BMBF) to investigate ways of integrating alternative technologies into the ongoing smelting process. This new approach produces iron in the smelter by way of direct reduction. As simulations go to show, natural-gas-based direct reduction could bring emissions down by more than 15 percent. Green hydrogen would later replace natural gas, a fossil fuel, to eradicate CO₂ emissions in steelmaking.

AWARDS 2018

Last year saw Fraunhofer researchers win a host of prizes for first-class scientific achievement. Among these awards were a number of major national and international honors for advances made in the field of applied research. We pay tribute to these projects.



EARTO Innovation Award

New multi-organ chip reduces animal testing

Each year, the European Association of Research and Technology Organisations (EARTO) presents awards for innovations with a significant social or economic impact. In 2018, a multi-organ chip developed by the Fraunhofer Institute for Material and Beam Technology IWS was awarded third prize in the "Impact Expected" category.

This microsystem simulates the bloodstream and organs of animals or humans. In many cases, it can obviate the need for animal testing and also accelerate the development of new drugs and cosmetics. Moreover, it is destined to be a vital component of personalized medical care. A team based in Dresden and led by Dr. Frank Sonntag and Dr. Udo Klotzbach

has been working on the multi-organ chip since 2009. Using a laser, the team cuts artificial blood vessels and chambers for tissue and other functional elements into layers of plastic film. These layers of plastic film are stacked and joined together. Sensors, valves, pumps, connectors, mass exchangers and electronic controls are then added. There are also plans to use machine learning in order to improve analysis results.

The latest parallel-flow version of the multi-organ chip replicates the different rates of blood circulation in organs. In the race to find alternatives to animal testing, the multi-organ chip offers a key advantage: it can simulate complex processes, most particularly the distribution of active substances in the bloodstream and between organs. What's more, it is highly compact, no bigger than a regular pack of tablets.



European Silver Economy Award, presented by the SEED consortium

A sensor, app and portal for the aging society

Mobility, fitness and safety are universal requirements for people of all ages. At the end of 2017, the Netherlands company Gociety Solutions launched a device that combines a range of features designed to protect the aged. Developed with the support of Fraunhofer Portugal, the wearable GoLiveClip comprises an alarm button that notifies designated contacts, a fall detector that automatically calls for help should the user be unable to activate the alarm button, and a fall risk monitor that can determine whether there is imminent danger of the user falling. The GoLiveClip is used in combination with a GoLivePhone app. Other services include a GoLiveAssist web portal, which provides authorized carers with real-time information on the user's health metrics.

The market-ready GoLiveClip and its suite of digital services feature two developments by Fraunhofer's Portuguese affiliate, Associação Fraunhofer Portugal Research: the Smart Companion, which features various apps for older people, thereby enabling them to continue taking an active part in the digital world; and Pandlets, a new architecture for embedded electronics in wireless devices, which is seamlessly integrated in the Android operating system.

In May 2018, the GoLiveClip was honored with the European Silver Economy Award in the category dedicated to non-profit organizations. The European Silver Economy Awards have been launched as part of Horizon 2020, the current European Union Framework Programme for Research and Innovation. Their purpose is to raise public awareness of innovative solutions that improve the quality of life for an aging population.



EU Prize for Cultural Heritage

3D digitization helps preserve historical artifacts

In 2018, the European Commission and Europa Nostra, a leading movement for the preservation of Europe's cultural heritage, presented awards for outstanding contributions in the areas of conservation, research, honorary work, education, training and building public awareness. All in all, 29 prizewinners from 17 countries were honored. Among the winners in the category for research was CultLab3D, a system developed by the Fraunhofer Institute for Computer Graphics Research IGD. The award came in recognition of Fraunhofer IGD's innovative research in 3D mass digitization and implementation of high-definition 3D scans as a means of preserving Europe's historical treasures for the enjoyment of coming generations. In its development of automated scanning technology, Fraunhofer IGD has made a key contribution toward safeguarding Europe's cultural heritage as a source of inspiration for the future.

The importance of this award was underlined by the presence at the ceremony of Frank-Walter Steinmeier, president of the Federal Republic of Germany, Placido Domingo, president of



Europa Nostra, and Tibor Navracsics, European Commissioner for Education, Culture, Youth and Sport.

Circular Materials Challenge

bioORMOCER® coatings for compostable plastic packaging

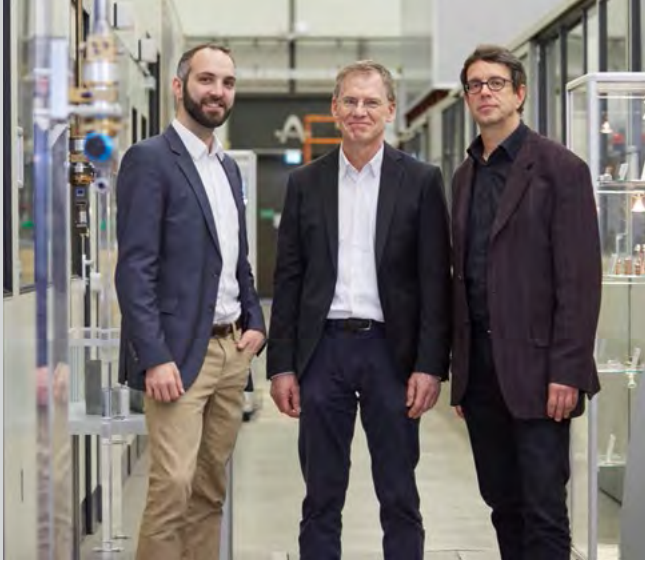
The Ellen MacArthur Foundation was founded in 2010 by pioneering yachtswoman Dame Ellen MacArthur, former holder of the record for the fastest solo circumnavigation of the globe. Its purpose is to promote sustainability and accelerate the transition to a circular economy. The foundation's groundbreaking work around the world has had such an impact that this topic is now firmly on the agenda of leading figures from the worlds of business, government and academia. In 2018, the foundation announced the winners of the Circular Materials Challenge, worth a total of US\$1 million, at the annual meeting of the World Economic Forum in Davos.

Among the five prizewinners was Dr. Sabine Amberg-Schwab. Together with her team from the Fraunhofer Institute for Silicate Research ISC, she was honored for the development of bioORMOCER® hybrid polymers. These anorganic-organic hybrid polymers are biodegradable and mark a milestone in the development of compostable packaging. "Our bioORMOCER® hybrid polymers remedy the weaknesses of previous biopolymers, which can now deliver the properties required for reliable packaging," she explains. When biodegradable packaging is coated with a bioORMOCER® barrier film, it becomes sufficiently impermeable to air and water vapor, thereby making it suitable for the food industry. These new coatings are now being optimized for use in standard industrial processes. In a further benefit, conventional plastic films covered with a bioORMOCER® coating can be more easily recycled as a monofilm.

European Commission logo for "HR Excellence in Research"
Outstanding working conditions for researchers

The HR Excellence in Research logo is reserved for organizations that can show they comply with the European Charter for Researchers and the Code of Conduct for the Recruitment of Researchers. For the European Commission, which awards the logo, compliance with this Charter & Code is a key indicator of an organization's success as a scientific body and attractiveness as an employer. At the same time, certification is of increasing importance for organizations applying to take part in EU projects. To obtain certification, research organizations must have a comprehensive human resources strategy for researchers (HRS4R). This covers a total of 40 criteria, including recognition of the profession, career development, value of mobility, transparent recruitment and fair selection.

Fraunhofer has been certified since the end of 2017. In awarding the logo, the Commission singled out for praise the working conditions at Fraunhofer, the career opportunities for young researchers and the high-caliber research environment. Aside from confirming the excellence of the HR work done at Fraunhofer, the logo also underscores the link between good research and good working conditions for researchers. And, last but not least, it also highlights the achievements of the people working in areas of the Fraunhofer administration that are related to research operations.



Berthold Leibinger innovation prize

Effective protection for metal coatings

The development of an innovative laser process for material deposition has been rewarded with the renowned Berthold Leibinger Innovationspreis conferred by the homonymous foundation. Known as EHLA (extreme high-speed laser material deposition), this process was developed at the Fraunhofer Institute for Laser Technology ILT and RWTH Aachen University. As well as being efficient in the use of resources and environmentally friendly, it also increases productivity. This is because the metal powder particles are melted directly in the laser beam, which boosts the process speed from the current maximum of a few meters per minute to up to 500 meters per minute. Moreover, using the new process, the material can be deposited to a thickness of between 10 and 250 microns, down from over 500 microns with the conventional method.

Together with Gerhard Backes and Jochen Kittel from the Chair of Digital Additive Production DAP at RWTH Aachen University, Dr. Andres Gasser, Wolfgang Kueppers and Thomas Schopphoven from Fraunhofer ILT already received the Joseph von Fraunhofer Prize for this development back in 2017. Since then, this process has been steadily gaining ground in industry. For example, IHC Vremac Cylinders from the Netherlands uses EHLA to produce components for offshore use, and TRUMPF Laser- und Systemtechnik GmbH in Germany now offers the EHLA process with its TruLaser Cell machines for the finishing of components with coatings resistant to wear and corrosion. Meanwhile, in China, the Fraunhofer ILT spin-off ACunity has recently delivered several EHLA systems to the Advanced Manufacture Technology Center, a state-run research organization, in order to pave the way for market rollout there.

Steel innovation prize

Micro steam turbine generates power and cuts CO₂

Every three years, the German Steel Federation honors exceptional innovations based on the material steel. The Stahl-Innovationspreis (Steel innovation prize), which was first presented in 1989, is divided into a number of categories. It is regarded as one of the major innovation awards in Germany. First place in the category for steel products went to a research team from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and its spin-off TURBONIK. Their award-winning development was an ultra-efficient and oil-free stainless-steel micro steam turbine for independent power generation. Steam is required for a host of industrial processes. Generating this so-called process steam consumes substantial energy and is a significant cost factor. The micro steam turbine from Fraunhofer UMSICHT uses excess process steam to generate electricity. This helps conserve resources. The micro turbine has no gearing, which enables very high speeds. This makes it up to 40 percent more efficient than conventional steam turbines. What's more, it does not require any lubrication with oil, which not only reduces maintenance costs but also benefits the environment. The micro turbine can be easily incorporated in operations that use process steam – in the pharmaceutical, food and textile industries, for example – and can substantially reduce overall energy costs, even for small plants.

A micro steam turbine from TURBONIK is already in operation at the energy company Energieversorgung Oberhausen AG (evo). It is powered by steam vented from the district heating network. It thus regulates the steam pressure while also generating electricity. The micro turbine produces 300,000 kWh of electricity a year. This corresponds to the power consumption of around 60 to 75 four-person households and therefore yields a substantial reduction in energy costs.

VISIONS

OF THE SHAPE OF THINGS TO COME

#WHATSNEXT: Moonshot visions from Fraunhofer

One of the highlights of every Netzwert Symposium are the elevator pitches, in which young researchers have 90 seconds to outline a business project. At stake is a cash prize and start-up capital of €25,000. In our anniversary year, competitors were invited to present their “moonshot vision” – in other words, a pioneering idea that in the next ten years will use Fraunhofer technology to solve one or other of the urgent problems facing the world. Over the course of two days, 20 researchers showcased their projects. The majority of them were in the areas of energy, medicine and the environment. In all, seven projects were commended.

Climbing robots to harvest solar energy on building facades

There’s no doubt that climate change is forcing us to rethink our energy strategy. One option here is solar energy, which provides a clean source of electricity and heating. Yet in order to cover our energy requirements, we would need to install a whole lot more solar panels, whether on roofs, building facades or in fields. Aside from the question of where to find the space, there is also the aesthetic consideration. This prompted Dr. Michael Hermann from Fraunhofer ISE to come up with what he dubs the “Faxel”: small robots that climb onto building facades in order to harvest solar energy. Once fully charged, they then descend automatically to the basement, where they surrender their power. The Faxel can be installed on new or refurbished buildings; no additional infrastructure is required. What’s more, the robots can be combined with plants or fitted with LEDs, thereby creating interesting design options. Over the next ten years, we could therefore see messages on building facades that are created by programmable LED panels fitted to robots. At the same time, these robots would also supply the buildings with solar power.

Flamingos inspire development of a microplastics filter

Microplastics are everywhere, even in the food chain, where they now present a health risk for animals and humans. In searching for a solution to this problem, Leandra Hamann has turned to nature for inspiration. The young researcher from Fraunhofer UMSICHT has based her development on a class of organisms known as suspension feeders. These are equipped with a special mechanism to filter out particles from water and ingest this particulate matter. Examples of this class include flamingos, whales and sea squirts. Microplastics are about the same size as these particles. This gave Hamann the idea of developing a bionic filter for microplastics based on the filter mechanism of various suspension feeders. All in all, she investigated 24 different organisms of this class and identified specific anatomical structures that might be of interest for building a bionic filter. In the future, bionic filters could well be used to sieve microplastics out of wastewater.

No heart attacks after a bath in this tub

Cardiovascular disease is one of major causes of death in Germany, accounting for almost 40 percent of all fatalities. Yet too few people go for regular checkups with their physician. Tobias Behr and Dr. Jens Langejürgen from Fraunhofer IPA have an ambitious plan: as of the year 2030, no more fatalities from infarction. Their idea is to make the checkup procedure as simple as possible – as simple as taking a bath. In a project known as LisBat, they have developed a special bathtub fitted with sensors and microphones. These record key health metrics, while the patient relaxes in the tub. A monthly session is all that is required. Using big data analytics, these readings are then processed in order to deliver a risk assessment of heart disease. That way, preventive action can be implemented well in advance.



Autonomous ships to recycle plastic refuse

The growing amount of plastic refuse in the world's oceans is one of the big problems of our age. It not only endangers hundreds of species but also causes economic damage running into billions. Various cleanup methods already exist, but none of them really offers an integrated approach. Katharina Reh and her team from Fraunhofer UMSICHT in the town of Sulzbach-Rosenberg want to change that. Her SeaCycle project envisages an autonomous fleet of ships equipped with object-recognition technology and other smart detection systems. By means of an onboard conversion process, for which the technology already exists, the plastic refuse fished from the water can then be used to produce fuel to power the ships. The vessels would also communicate with one another so as to coordinate operations and ensure arrival at the right place and right time. A project of this scale requires a wide range of expertise, meaning that all of the Fraunhofer Institutes would be called upon to contribute their know-how.

Bioprinted organs to relieve the donor shortage

In Europe, 140,000 people are currently waiting for a donor organ, and this list continues to grow. In the future, one way of alleviating this serious shortfall could be to use additive technologies to "bioprint" organs. The principle difficulty here lies in reproducing the highly complex structure of human organs. Now, however, a team led by Christian Freese from Fraunhofer IMM is working on a technique that will make it possible to bioprint each individual cell with extreme spatial precision during the additive manufacturing process. What's more, this process is fast. In other words, ten years from now, it may well be possible to order, via the Internet, a personalized kidney or even a heart.

Artificial trees to combat air pollution

Population growth and increasing mobility have led to a rise in emissions harmful to the environment. Options here include not only reducing those emissions, but also filtering them from the air. We already have substances that actively absorb CO₂ from the atmosphere. What's more, there are also materials that are able to convert this captured CO₂ into fuels or chemicals. Dr. Calogero Giancarlo Piscopo from Fraunhofer ICT aims to make use of this process. His ARTEMIS project envisages the use of artificial trees to capture CO₂ in metropolitan environments. Trees made of these special materials would be able to clean the air in our cities 24/7 and, at the same time, produce raw materials needed by society.

Smart skin sensors for advance detection of disease

Many human diseases also manifest themselves on the skin and can therefore be detected by means of spectral sensors. The project led by Dr. Katharina Holstein and Dr. Andreas Herzog from Fraunhofer IFF aims to use artificial intelligence to provide early detection of disease. In their vision, doctors in the future will be equipped with a small handheld device they call the Human SkinCorder. This device will be used in routine examinations to record and analyze individual patient data. At the heart of the concept is a global database containing a multitude of sensor data that provide the training dataset required for AI. Fraunhofer already has expertise in all the various technologies required to realize this project. It will, however, require intensive, interdisciplinary collaboration between different institutes in order to take on a project of this scale.

PEOPLE IN RESEARCH



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

PROF. DR. RER. NAT. ANDREAS VILCINSKAS

Biologist | Location head of the Bioresources branch of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen

Insects are regarded as the most successful group of animals on Earth. Their extraordinary biodiversity at the species level is also reflected at the molecular level. "In that sense, you could describe insects as a huge reservoir of active ingredients," says biologist Andreas Vilcinskis. "So, the question is, how do we tap into that and make it available to people for medicine, crop protection and industrial biotechnology?"

Entomology has fascinated Andreas Vilcinskis ever since he was a child. He began collecting butterflies when he was 12. "Insects come in so many different shapes and colors – that's what inspired my career in science," he says. He completed his "habilitation" – the postdoctoral qualification required to teach at universities in Germany – in zoology at the age of 34 and was appointed to his first professorship just one year later. Today, the 55-year-old researcher is a globally renowned molecular biologist and insect biotechnology expert. He has published 12 books and over 200 scientific papers and filed numerous patent applications. He runs the Institute for Insect Biotechnology at Justus Liebig University (JLU) Giessen and heads the Bioresources branch of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Giessen.

Vilcinskis is considered to be a pioneer in the field of insect biotechnology. As a doctoral student, he initiated lucrative partnerships with industry. During his postdoctoral research, he headed up projects with pre-approved funding for a large pharmaceutical company. "I recognized the huge economic

potential of insect biotechnology a long time ago," he says. In 2009, Vilcinskis established the Bioresources business area at Fraunhofer IME, thus creating a platform for insect biotechnology that plays a leading role in its field in both Germany and the EU. In 2011, he began publishing a series of the world's first books on insect biotechnology, coining the term "yellow biotechnology" in the process. In 2015, Vilcinskis established the world's first academic institution for insect biotechnology at JLU Giessen, eventually going on to establish the first international Master's degree course in Insect Biotechnology and Bioresources in 2017.

"What I admire about the Fraunhofer-Gesellschaft is its focus on applied research for people," Vilcinskis says. "It's also the perfect place to carry out interdisciplinary research because it covers so many different skill sets. Equally, insect biotechnology is the perfect business field for Fraunhofer due to its rigorous translational research approach." One of his overarching goals is to develop the use of highly biodiverse organisms as a resource for the bioeconomy. His research focuses primarily on identifying natural sources of new antibiotics and developing innovative control options for pest and vector insects as biological alternatives to pesticides. "We can also help solve the problem of how to feed the world's growing population by using insects as alternative sources of protein, fats and other nutrients," Vilcinskis argues. "My aspiration is that my research work should contribute toward solving some of humanity's most pressing problems."



DR. RER. NAT. ASTRID BINGEL

Physicist | Research fellow at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena

Intelligence and talent are key factors in becoming a successful researcher – and Astrid Bingel is not short of either! She passed her university entrance exams with straight As and then rose to an even greater challenge when she entered the Faculty of Physics and Astronomy in Jena: “The things we were learning were so overwhelmingly complex that it almost killed us!” It also proved beyond doubt that the student had even more of the qualities that make a good researcher, namely diligence, persistence and inquisitiveness.

It was optical coatings that first sparked her thirst for knowledge. While she was studying physics at Friedrich Schiller University Jena, she heard that the Fraunhofer Institute for Applied Optics and Precision Engineering IOF was looking for an intern to conduct research into silver island films in the Optical Coatings department. Bingel took up the challenge – and she has been delving into this fascinating topic ever since. She dedicated both her diploma thesis and her doctoral thesis to optical coatings, obtaining outstanding grades for both. The research she conducted as an intern in 2008 focused on producing small silver islands that exploit plasmonic effects to generate a colored coating, but her dissertation and thesis addressed quite different challenges. Both papers focused on the development of transparent, conductive coating systems into which silver was subsequently integrated with the aim of growing it into a smooth and homogenous coating that was as thin as possible. Bingel’s enthusiasm for the physics of optical coatings is immediately obvious: “I find it fascinating that you can achieve such amazing effects with just a few ultra-thin films of material – and I love being able to contribute toward developing industrial-scale processes that make more

economical use of energy and resources.” Important coating systems of this type include anti-reflective coatings in spectacle optics and highly reflective surfaces in mirror systems for astronomical and space applications, as well as beam splitters and optical filters. These transparent, conductive coatings play a key role as transparent electrodes in flat-panel displays, touchscreens, LEDs and OLEDs.

In 2012, Bingel’s dissertation on transparent and conductive Al-doped ZnO coatings received the Silicon Science award from CiS Forschungsinstitut für Mikrosensorik GmbH in the category for outstanding dissertations from the field of sensors, actuators, microsystem engineering and photovoltaics. In 2017, she received the Green Photonics young talent award for her dissertation on tailored TCO coatings and coating systems. She added another award to her collection one year later in the form of the Hugo Geiger Prize, which the Fraunhofer-Gesellschaft and the Bavarian Ministry of Economic Affairs award jointly for outstanding doctoral theses with an application-oriented focus.

Bingel is now the mother of a one-year-old son who she and her partner care for together. Her 12 months of parental leave, which came to an end in early November 2018, have left her with just as much enthusiasm for research as ever, and she has now plunged wholeheartedly back into the world of optical coatings at Fraunhofer IOF. She could certainly never be accused of a lack of motivation: “We are constantly developing new technologies for new products – how could anyone find that boring?”

PROF. DR.-ING. CHRISTIAN BAUCKHAGE

Computer scientist and physicist | Lead scientist for Machine Learning at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS | Scientific director of the Fraunhofer Center for Machine Learning in the Fraunhofer Cluster of Excellence Cognitive Internet Technologies (CCIT)

Christian Bauckhage believes that technology's primary purpose should be to serve people. From an early age, he found himself wondering how clever inventions could be used to support certain human capabilities. He came closer to achieving this goal when he embarked on a degree in computer science and physics in Bielefeld, and things took a particularly inspiring turn during his research visit to the INRIA institute in Grenoble at the age of 24. His research career advanced in leaps and bounds: in 2008, while working as a senior research scientist at Telekom Labs in Berlin, Bauckhage was awarded a professorship at the University of Bonn. He started work at the Bonn-Aachen International Center for Information Technology as professor of Computer Science and Pattern Recognition, simultaneously taking up the post of lead scientist for Machine Learning at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS – a combination of two truly fascinating jobs. The applied nature of Fraunhofer projects – particularly those that involve finance, Industrie 4.0 and medical technology – provide him with an appealing contrast to his teaching and research activities.

"I've been conducting research into machine learning for 20 years. Hardly anybody was interested for the first 17 years – but now everyone is!" says the 46-year-old researcher. He points to a quantum leap in artificial intelligence that occurred some eight years ago when a number of trends converged. This paved the way for algorithms to handle big data, reduced the price of high-performance computer hardware to reasonable levels and triggered some significant progress

in our understanding of deep architecture thanks to neural networks. Now that everyone is talking about artificial intelligence, or AI – a term that Bauckhage argues should really be replaced by "artificial cognition" – he often receives invitations from Frankfurt banks and the German Chancellery to attend executive meetings as an expert in this field.

One of Bauckhage's keynote presentations is on artificial intelligence in games, and he is a firm advocate of measuring progress in this area in terms of the number of "insults to humanity", as he puts it. Researchers have been attempting to use neural networks to create computer models of the human brain ever since 1943. And, since the 1970s, computer programs have been defeating human world champions at strategy games such as backgammon and chess. A new frontier was breached in 2016 when the Google DeepMind software AlphaGo beat South Korean Go world champion Lee Sedol. Bauckhage was suitably impressed: "As a computer scientist, I knew that meant anything was possible!" Nowadays, one of his key goals is to help ensure that Germany reaps real benefits in the global race toward digitalization. He pursues this goal as a consultant, researcher and lecturer, often working long into the night and at weekends. Though acknowledging the legitimacy of ethical considerations, Bauckhage insists these are outweighed by the opportunities that artificial intelligence offers when it comes to analyzing data. He argues that one of the central tenets of this debate should be the very thing that originally inspired him – namely the fact that AI systems can diagnose certain diseases faster and more accurately than any human physician.





DR. EVA EGGELING

Mathematician | Managing director of Visual Computing Technologies at Fraunhofer Austria Research GmbH | Lecturer in Visual Computing at TU Graz

Mathematics comes naturally to some people. Even as a child, Eva Eggeling had a thing for numbers and clear, logical patterns, and she still can't help neatly arranging her pens on the edge of the table as we talk. She was also influenced by her father, who ran the computer center in Jülich, so a career in mathematics seemed like a foregone conclusion. In 1988, she embarked on a degree course in applied mathematics at the University of Bonn, subsequently switching to the University of Cologne to take her doctorate. She showed remarkable enthusiasm for programming algorithms to solve partial differential equations. While still a student, she signed up to help out as a research assistant at the Institute for Algorithms and Scientific Computing, which at that time formed part of the German National Research Center for Information Technology in Sankt Augustin. This institute was subsequently incorporated into the Fraunhofer-Gesellschaft as the Fraunhofer Institute for Algorithms and Scientific Computing SCAI. Under the tutelage of her doctoral supervisor, Professor Ulrich Trottenberg, she eventually went on to become a research fellow at Fraunhofer SCAI.

Eggeling has particularly fond memories of one of her first projects, which focused on software-based process optimization in the automotive industry. The project was extremely successful, picking up an award and garnering considerable respect from her colleagues at that time, who were mostly men. Word of her talent quickly spread to the international stage, and she was soon asked to join a team of scientists led by Israeli mathematics professor Shlomo Ta'asan at Carnegie Mellon University in Pittsburgh. She accepted this invitation in 2006, heading to the U.S. with her husband – a qualified automotive mechatronics technician – and her daughter.

Eggeling spent three exciting years in the U.S., working on modeling and simulation methods in materials research at one of the Materials Research Science and Engineering Centers (MRSECs). But then she received another life-changing phone call asking her to head up the Visual Computing business area of Fraunhofer Austria Research GmbH in Graz – an offer she couldn't refuse. "The opportunity to make a real difference in a management position was simply too good to turn down," she says. The move into management also meant leaving behind pure research, however, so this next step in her career had a bittersweet edge.

With a second child now also on the scene, the family of four once again faced the challenge of settling down in a foreign country, this time Austria. For Eggeling, the degree of upheaval felt equivalent to their previous move to the U.S., and it also meant adapting her mathematical skills to the field of visual computing. With Eggeling at the helm, the business area grew to a team of 11. They now tackle a diverse assortment of projects ranging from transportation infrastructure optimization to Industrie 4.0. "We help people use visualized data to make decisions," says Eggeling, summing up her team's work.

Her family is now fully integrated in their new home. Her elder daughter is studying molecular biology while her younger daughter is keen to forge a career in artistic gymnastics. Asked whether the future might hold more surprises, she says her mind is open: "Something always seems to crop up once I've been somewhere for a while," she says with a smile.



DR. RER. NAT. JOHANNA LEISSNER

Chemist | Glass specialist | Scientific representative of Fraunhofer Institutes IAP, IBP, ICT, IGB, IMW and ISC at the Fraunhofer EU Office Brussels

From historical buildings and monuments to art objects and ancient manuscripts, the task of protecting cultural assets is a complex business. The fact that Fraunhofer plays such a key role in European research into the preservation of cultural heritage is partly due to the efforts of Johanna Leissner.

After studying chemistry at the universities of Würzburg and Münster, Leissner headed to the U.S. to spend a year at the Georgia Institute of Technology in Atlanta. Having excelled in her doctoral program, she was appointed to the Fraunhofer Institute for Silicate Research ISC in Würzburg where she joined the working group for the protection of cultural property. In 1992, she succeeded in securing the institute's first EU project with funding approaching one million euros. Their task was to develop glass sensors for museum display cabinets and interiors and to protect historical stained glass windows. The choice of topic was a stroke of luck for the young scientist. Leissner had discovered a passion for stained glass from an early age. As a 13-year-old, one of her formative experiences was visiting the High Gothic cathedral of Chartres and seeing its stained glass windows, for which a new blue pigment was developed in the 13th century. Leissner garnered numerous national and international awards for her outstanding research work at Fraunhofer ISC. These included the first award for "Success stories from EU Research" presented to her and her team in Paris in 1997 for the EU project "Assessment and Monitoring the Environment of Cultural Property". She was subsequently appointed as an expert advisor to the EU Commission. From 2001 to 2005, she was the Fraunhofer-Gesellschaft's first seconded national expert to the Commission's Directorate-General for Research and Innovation. She spent six months providing maternity leave cover as head of the

Fraunhofer EU Office Brussels before assuming her current position as scientific representative of Fraunhofer Institutes IAP, IBP, ICT, IGB, IMW and ISC for the European Union.

In addition to networking and lobbying, her responsibilities also include project acquisition in the face of fierce competition for EU funding. "Nowadays, being chosen for an EU project is a bit like winning a mini Nobel Prize!" says Leissner. This was certainly the case with the EU project Climate for Culture, which ran from 2009 to 2014 with Leissner at the helm and involved 27 partners from 16 countries researching the effects of climate change on the preservation of cultural heritage. Fraunhofer has done some pioneering work in this field. This was the first time scientists had combined climate modeling with building simulation to predict what effect the changing European climate will have on the indoor climate and energy requirements in historical buildings. Protecting cultural heritage is essentially a niche topic for Fraunhofer – and that means it requires plenty of supporters and solid networks. To address this need, Leissner collaborated with the Leibniz Association and the Prussian Cultural Heritage Foundation to establish the Research Alliance Cultural Heritage in 2008. She also co-founded the "Sustainability and Research" working group. Two years later, this gave rise to the Fraunhofer Sustainability Network, which Leissner still represents in Brussels today. She feels confident that their efforts will continue to make an impact in the future. "Our work is held in high esteem by the institutes and the Executive Board – and that has enabled us to shine a spotlight on cultural heritage research across Europe. Our job now is to preserve, expand and consolidate the knowledge and skills that Fraunhofer has acquired."



DIPL.-ING. MIRKO RIEDE

Mechatronics engineer | Group manager of 3D Manufacturing at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden

Take some solid technical expertise and craftsmanship, add a healthy dose of creativity and nonconformity, and you have the perfect recipe to create something truly unique! This proved to be the perfect combination for Mirko Riede, the Leipzig-born son of a classical singer and a professional toolmaker. Together with his colleague Frank Brückner, he received the Joseph von Fraunhofer Prize last May at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden in recognition of their outstanding work on improving the efficiency of aircraft engines. In a joint research project, the two engineers used additive manufacturing to develop microstructures that can be used to extend the lifetime of thermal barrier coatings. Their contribution will help achieve significant reductions in airplane fuel consumption and pollutant emissions. The research project was carried out in close collaboration with aero engine specialist Rolls-Royce. The engines have been in service on Airbus long-haul aircraft since February 2018. "It's very important to me to see my research results actually being put into practice," says Riede.

Thirty-four-year-old Riede spent the first six years of his life in the former GDR, and he argues that this period and the subsequent upheaval of reunification made a lasting impact on him. At that time, he says, people had little choice but to rely on themselves and tackle problems by inventing unconventional solutions. As a child, Riede enjoyed spending time with his father in his basement workshop, tinkering with soap boxes and model airplanes. This kindled an early passion for aviation and engines of all kinds.

Riede went on to study mechatronics in Dresden. This was the field that most appealed to his interests, because he was fascinated by both automation technology and mechanics: "I always feel the solution lies in a combination of both." He enjoyed the interdisciplinary approach and the applied nature of the course. During his studies, the young researcher joined Fraunhofer IWS in Dresden as a research assistant, where he got involved in laser metal deposition. What he loves about Fraunhofer is the ability to pursue academic and applied paths at the same time and quickly verify how research findings play out in practice. Riede's talents as a scientist quickly became clear, and it wasn't long before he had picked up the institute's prize for the best work by an up-and-coming researcher in recognition of his insights into the additive manufacturing of microstructures conducted as part of his thesis. His findings would subsequently be incorporated in research on aircraft engines.

Over the years, Riede's career at Fraunhofer has taken him from a research fellow to a group manager in the field of 3D manufacturing. He is also now the proud father of a son, born just over a year ago. Riede has already pinpointed many new areas in which Fraunhofer IWS could apply additive manufacturing methods in component manufacturing. These include plant engineering and, in particular, the medical device and aerospace sectors, which he promotes in his role as group manager. In terms of his own personal development, Riede places a key emphasis on the importance of scientific and technical progress: "I'm most interested in things that offer broad benefits to society."

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 acquired there to start up their own businesses. Here we present just a few of the companies that were founded or opened for business last year.



Volucap GmbH**New solutions for “walkable” movies**

Founded in Potsdam in May 2018, the high-tech start-up Volucap GmbH is a spin-off of the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI. In June 2018, Volucap became the first company in continental Europe to open a commercial volumetric video studio. “We’re looking at a huge international growth market,” says Sven Bliedung, CEO of Volucap GmbH. Located in the grounds of the Babelsberg Film Studio, the new studio is equipped with 3D Human Body Reconstruction (3DHBR) technology developed at Fraunhofer HHI. This enables people and objects to be filmed in three dimensions in real time and then transferred as holograms into virtual environments, where they can be viewed from all sides just like computer-generated 3D models. The studio uses 32 cameras arranged around a four-meter-high recording area, which is illuminated by light panels. “We can capture and process a person’s every movement from every angle,” says Peter Kauff, head of the Vision and Imaging Technologies department at Fraunhofer HHI.

In spring 2018, the regional investment bank of the federal state of Brandenburg approved a two-million euro funding grant for a consortium consisting of the Fraunhofer-Gesellschaft, ARRI Cine Technik GmbH & Co. Betriebs KG, Interlake System GmbH, Studio Babelsberg AG and UFA GmbH. The new studio’s primary use is currently in the field of advertising trailers and learning applications for virtual and augmented reality productions as well as in the gaming industry. Over the next few years, the company is planning to further improve image quality to enable the technology to be used in feature films.

**Cellbox Solutions GmbH****Mobile incubator for transporting living cells**

Living cells can save lives – but only if they can be transported to where they are needed. Currently, fragile cells are generally shipped in a frozen state, but this impairs their quality and leads to significant amounts of cell death. The cell transport box developed by the Fraunhofer Research Institution for Marine Biotechnology and Cell Technology EMB can be used to transport living cells under laboratory conditions without suffering these losses. Professor Kathrin Adlkofer, CEO of Fraunhofer EMB’s spin-off Cellbox Solutions GmbH, is now working with her team on a strategy to market the boxes: “Medicine is currently undergoing a major transformation. The focus is shifting from treating patients to curing them. When it comes to transporting cell therapeutics and other biological materials, there is no other comparable solution anywhere in the world that can offer the same level of logistical support for timely, cost-efficient, personalized therapy designs while maintaining the high quality of the cells.” There are some incubators on the market that can heat or cool the contents, says Adlkofer, but none that can offer the optimum temperature in the presence of carbon dioxide. Users can set the required temperature, which is then maintained automatically by the transport box. At the same time, the box produces the carbon dioxide concentration required by the cells.

The molecular biologist and biotech entrepreneur was taken on by Fraunhofer EMB in the summer of 2016 as head of the Cell Technology department and tasked with finding technologies that could be usefully exploited. She immediately spotted the box which, at that point, was only used for in-house purposes. “I saw its potential straight away,” says



Fraunhofer Institute spin-offs

Adlkofer. The new company was spun off in December 2016. Since then, a research team consisting of members of Fraunhofer EMB and the Business Development and Technology Transfer Corporation of Schleswig-Holstein has been working on the technical optimization of the product and preparing for its market launch. Keen to ensure that the box can be transported not only by road or sea, but also by air, the researchers developed another variant of the cellbox that incorporates an unpressurized feed source of carbon dioxide in the form of dry ice. Production of the boxes by a qualified partner company is scheduled to start in early 2019.

MotionMiners GmbH
Improved efficiency and ergonomics for manual work processes

Untapped potential for improving efficiency and ergonomics can often be found in situations where employees carry out manual work in industrial or logistics settings. The company MotionMiners GmbH – a spin-off of the Fraunhofer Institute for Material Flow and Logistics IML – can help unlock this potential. It uses a technique called Motion-Mining®, which involves capturing the workers' movements and activities using mobile sensors (wearables) and miniature radio transmitters (beacons). This data is then fed into an AI, which reconstructs the steps in the process and delivers key figures for a range of analyses. These might include evaluating the productivity and efficiency of a workflow or analyzing ergonomics in order to identify potential improvements. "Our method enables us to do two key things: firstly, to quantify the time each process takes and the inefficiencies it contains and, secondly, to improve employees' health and well-being by recommending more ergonomic sequences of movements or the use of more appropriate tools, for example," says

Sascha Feldhorst, one of the three company founders who currently still works at Fraunhofer IML. To protect employees' rights and privacy, the data is anonymized as it is collected and then aggregated for further processing.

The company, which was founded in October 2017, receives funding from the German Federal Ministry for Economic Affairs and Energy (BMWi) as part of an EXIST Research Transfer program. The start-up has received numerous awards since it was founded, including first prize in the 2017 Digital Logistics Awards, the TU Startup Awards and the Start2Grow business plan competition. The team also took one of the top prizes in the Digital Innovations ideas competition organized by the BMWi. Once the first phase of EXIST funding comes to an end in July 2019, the company and its 21 employees should be ready to stand on their own feet. Things are already looking up: as well as winning awards, the team of founders has already signed up more than 12 customers, including big names such as Bayer, Hugo Boss and Skoda.

Purenum GmbH
Novel adhesive to remove kidney stone fragments

Each year, over one million people in Germany alone are afflicted by kidney stones. Thousands of patients undergo endoscopic procedures to remove the kidney stones but, in many cases, tiny fragments of stone are left behind in the kidneys, leading to a recurrence of the problem in about 50 percent of cases. Now, scientists at the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM in Bremen have succeeded in developing a biomimetic medical adhesive to remove kidney stone fragments in endoscopic procedures. In December 2017, the company Purenum GmbH was spun off from Fraunhofer IFAM to take this technology to the next level.

“The adhesive takes effect underwater in a matter of seconds, without sticking either to the kidney mucosa or the surgical instruments,” says Manfred Peschka, co-founder and CEO of Purenum GmbH. Once the large kidney stones have been extracted, the remaining fragments are bound together with the adhesive, making them easy to remove. The groundwork for this development was laid in collaboration with urologists in the GO-Bio project mediNiK sponsored by the German Federal Ministry of Education and Research. Financing for the spin-off came from a number of sources, including High-Tech Gründerfonds (HTGF) and BAB Beteiligungs- und Managementgesellschaft Bremen, a subsidiary of Bremer Aufbau-Bank (BAB).

Before it can be launched in around two years’ time, the adhesive must first be certified for use. “Developing medical devices is a long and costly process. It’s essential to forge ties with qualified research partners and users in clinical settings,” says Dr. Ingo Grunwald, the second co-founder and scientific director of Purenum GmbH. The spin-off is now investigating further potential applications, including using the adhesive for the joining of bone splinters.

doks.innovation GmbH

Automated stocktaking for lean logistics

Companies are required by law to carry out inventories to record stock levels. These are labor-intensive and time-consuming, and often prone to error. inventAIRy® makes the whole process easier. With its sophisticated sensors and camera technology, the automated flying drone can check stock levels autonomously and record the logistical items required to carry out an inventory. inventAIRy® is one of four products from the company doks.innovation GmbH. Founded



in 2017 as a spin-off from the Fraunhofer Institute for Material Flow and Logistics IML in Dortmund, the logistics start-up aims to use drones, sensor technology and intelligent software to boost the digitalization of companies’ in-house transportation and stocktaking processes. The data – acquired in the form of a digital twin – is transformed into relevant information using machine learning algorithms. It can then be used to optimize the planning and configuration of the processes involved. “Our solutions cut costs by 70 to 80 percent and reduce transportation times by a third,” says CEO Benjamin Federmann.

The company’s solutions are based on various sources, including the results of the InventAIRy research project run by the German Federal Ministry for Economic Affairs and Energy and the DelivAIRy research project carried out in-house at Fraunhofer. The start-up doks.innovation GmbH began marketing its products in January 2018. Its portfolio includes inventAIRy® for automated stocktaking in pallet stores and high-bay racking, summAIRy® for automated stocktaking outdoors, delivAIRy® for automated air transportation on factory premises and adamONE® for automated data capture using sensors in logistics and production environments. Within the space of just a few months, the company acquired multiple customers from the industrial and logistics sector, including global players such as BMW and Mars. The start-up currently employs 15 people at its headquarters in Kassel and at its Digital Hub Logistics offices in Dortmund and Hamburg. Shares in the company are held by the founders, the Fraunhofer-Gesellschaft, Metamorphoses, Gecoin and mind.fabric.



doks.



FINANCIAL REPORT

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BALANCE SHEET AT DECEMBER 31, 2018

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

ASSETS	€	€	2018 €	2017 € (1000)
Current assets				
Cash and cash equivalents		162,500,264.17		184,549
Marketable securities		384,658,683.04		337,943
Accounts receivable and other current assets				
Trade receivables	222,741,640.47			237,075
Receivables from the federal and state governments relating to base funding	25,399,131.88			27,276
relating to project billing, including contract research	146,900,795.04			157,967
relating to pension and compensated absence provisions	<u>72,324,200.00</u>			<u>66,018</u>
	244,624,126.92			251,261
Accounts receivable from associated companies	13,131,916.62			11,738
Other current assets	<u>127,761,606.48</u>			<u>135,428</u>
		608,259,290.49		635,502
Inventories		61,922,110.16		34,742
Prepaid expenses and deferred charges		<u>92,207,819.94</u>		<u>12,633</u>
Total current assets			1,309,548,167.80	1,205,369
Intangible assets			55,309,597.75	27,081
Property, plant and equipment			2,060,104,130.84	1,932,593
Financial assets			<u>20,624,113.86</u>	<u>21,164</u>
Total assets			<u>3,445,586,010.25</u>	<u>3,186,207</u>
Trust assets			33,625,585.86	27,120

LIABILITIES AND EQUITY	€	€	2018 €	2017 € (1000)
Current liabilities				
Trade payables		109,551,885.96		103,514
Unappropriated grants from the federal and state governments relating to base funding	187,631,256.83			210,845
relating to project billing	<u>110,067,719.98</u>			<u>63,778</u>
		297,698,976.81		274,623
Accounts payable to associated companies		1,223,834.23		344
Other current liabilities		<u>6,384,599.08</u>		<u>9,560</u>
Total current liabilities			414,859,296.08	388,041
Deferred income			122,182.20	86
Provisions for pensions and similar obligations			9,224,200.00	9,288
Other provisions			164,346,337.50	148,030
Special reserves				
License-fee revenue reserve		384,908,285.76		338,908
Grants relating to non-current assets		2,120,977,163.63		1,964,583
Grants used to finance current assets		265,151,973.01		247,555
Present value of deferred income from patent deal		<u>69,485,479.17</u>		<u>73,261</u>
			2,840,522,901.57	2,624,307
Equity				
Capital of the non-profit organization				
Carried forward	15,232,810.81			15,149
Retained earnings	<u>54,556.60</u>			<u>84</u>
		15,287,367.41		15,233
Restricted reserve		<u>1,223,725.49</u>		<u>1,222</u>
Total equity			<u>16,511,092.90</u>	<u>16,455</u>
Total liabilities and equity			<u>3,445,586,010.25</u>	<u>3,186,207</u>
Trust liabilities			33,625,585.86	27,120

INCOME STATEMENT FOR THE FINANCIAL YEAR 2018

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

	€	€	2018 €	2017 € (1000)
Revenue from base funding				
Federal government		768,020,325.74		604,266
State governments		<u>123,335,622.93</u>		<u>97,807</u>
			891,355,948.67	702,073
Revenue from own activities				
Revenue from research and development activities				
Federal government: Project funding		526,779,879.01		480,288
Contracts		14,542,761.43		9,446
State governments: Project funding		161,993,740.72		137,107
Contracts		2,329,600.87		1,431
Business, industry and trade associations		691,861,271.01		692,148
Research funding organizations and other sources		<u>188,248,979.69</u>		<u>187,623</u>
		1,585,756,232.73		1,508,043
Other revenue		<u>5,446,008.80</u>		<u>9,831</u>
Total revenue			1,591,202,241.53	1,517,874
Increase in work in progress		29,127,444.96		39,358
Other internally constructed and capitalized assets		8,178,808.27		7,341
Other operating income		43,325,758.04		28,666
Income from equity investments		4,298,102.69		1,728
Other interest and similar income		<u>1,233,098.42</u>		<u>928</u>
			86,163,212.38	78,021
Total base funding and revenue from own activities			2,568,721,402.58	2,297,968
Change in special reserves				
License-fee revenue reserve		-46,000,000.00		-40,000
Grants relating to non-current assets		-161,353,933.03		-58,362
Grants used to finance current assets		<u>-17,596,862.93</u>		<u>-11,499</u>
			-224,950,795.96	-109,861
Total income available to cover expenditure			<u>2,343,770,606.62</u>	<u>2,188,107</u>

	€	€	2018 €	2017 € (1000)
Cost of materials		381,114,801.75		357,952
Personnel expenses		1,350,181,996.21		1,247,808
Amortization of intangible assets and depreciation of property, plant and equipment		282,977,580.78		285,723
Other operating expenses		324,312,426.86		294,234
Amortization of financial assets and current marketable securities		4,451,810.77		1,857
Interest and similar expenses		<u>675,483.65</u>		<u>599</u>
Total expenditure			<u>2,343,714,100.02</u>	<u>2,188,173</u>
Net income for the year			56,506.60	-66
Transfer from reserves			-	152
Transfer to reserves			<u>-1,950.00</u>	<u>-2</u>
Retained earnings			54,556.60	84
Allocation to capital of the non-profit organization			<u>-54,556.60</u>	<u>-84</u>
			<u>-</u>	<u>-</u>

RECONCILIATION BETWEEN INCOME STATEMENT AND PERFORMANCE STATEMENT (CASH-BASIS ACCOUNTING) 2018

Income/receipts	Performance statement €	Non-profit organization capital €	Reconciling items €	Income statement €
Income/receipts				
from base funding	885,049,448.67		6,306,500.00	891,355,948.67
from research and development activities	1,619,619,292.39		-33,863,059.66	1,585,756,232.73
from other sources	995.08		5,445,013.72	5,446,008.80
Increase in work in progress			29,127,444.96	29,127,444.96
Other internally constructed and capitalized assets	8,178,808.27			8,178,808.27
Other income	49,256,759.42	309,598.75	-709,399.02	48,856,959.15
Total income/receipts	2,562,105,303.83			
Change in special reserves				
License-fee revenue reserve			-46,000,000.00	-46,000,000.00
Grants relating to non-current assets				
Allocations to special reserves (capital expenditure)			-444,539,378.29	-444,539,378.29
Reversal of special reserves (depreciation)		43,762.92	283,141,682.34	283,185,445.26
Grants used to finance current assets	-17,596,862.93			-17,596,862.93
Change in grants receivable relating to pension and compensated absence provisions	6,306,500.00		-6,306,500.00	
Total business volume (cash basis)	2,550,814,940.90	<u>353,361.67</u>	<u>-207,397,695.95</u>	<u>2,343,770,606.62</u>

Expenditure/disbursements	Performance statement €	Non-profit organization capital €	Reconciling items €	Income statement €
Expenditure/disbursements				
Cost of materials	348,627,635.99	25,355.48	32,461,810.28	381,114,801.75
Personnel expenses	1,362,422,156.13	640.00	-12,240,799.92	1,350,181,996.21
Amortization of intangible assets and depreciation of property, plant and equipment		187,709.21	282,789,871.57	282,977,580.78
Other operating expenses	349,054,611.52	83,150.38	-19,698,040.62	329,439,721.28
Expenditure as per the income statement				2,343,714,100.02
Change in special reserves				
License-fee revenue reserve	46,000,000.00		-46,000,000.00	
Capital expenditure (current and major infrastructure)	444,710,537.26		-444,710,537.26	
Net income for the year		-56,506.60		56,506.60
Total business volume (cash basis)	2,550,814,940.90	<u>353,361.67</u>	<u>-207,397,695.95</u>	<u>2,343,770,606.62</u>

PERFORMANCE STATEMENT FOR INDIVIDUAL FRAUNHOFER ENTITIES

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding
		2018 € (1000)	2018 € (1000)	2018 € (1000)	2018 € (1000)
Fraunhofer ICT Group					
Algorithms and Scientific Computing SCAI	Sankt Augustin	10,931.1	1519.0	8794.9	3655.1
Applied and Integrated Security AISEC	Garching b. München	9203.6	329.8	6719.2	2814.1
Applied Information Technology FIT	Sankt Augustin	19,075.5	981.7	15,177.3	4879.8
Communication, Information Processing and Ergonomics FKIE	Wachtberg	7631.0	315.5	6384.2	1562.3
Computer Graphics Research IGD	Darmstadt, Rostock	16,951.2	1008.9	11,071.7	6888.4
Digital Media Technology IDMT	Ilmenau, Oldenburg	14,514.7	441.7	8797.8	6158.6
Digital Medicine MEVIS	Bremen	9576.9	250.7	6022.6	3805.0
Embedded Systems and Com- munication Technologies ESK	München	5597.3	234.5	3887.8	1944.0
Experimental Software Engineering IESE	Kaiserslautern	13,639.3	764.5	11,473.1	2930.6
Industrial Mathematics ITWM	Kaiserslautern	27,941.8	2277.5	20,802.9	9416.4
Intelligent Analysis and Information Systems IAIS	Sankt Augustin	21,161.1	944.6	17,074.2	5031.5
Open Communication Systems FOKUS	Berlin	32,704.9	992.2	26,921.6	6775.5
Optronics, System Technologies and Image Exploitation IOSB	Karlsruhe, Ettlingen Ilmenau, Lemgo	33,416.4	2820.0	24,482.9	11,753.5
Secure Information Technology SIT	Darmstadt	11,254.8	504.7	8242.6	3516.9
Software and Systems Engineering ISST	Dortmund	4726.3	294.4	3353.1	1667.6
Transportation and Infrastructure Systems IVI	Dresden	11,092.2	2418.2	11,023.7	2486.7
Central office – Fraunhofer ICT Group IUK-GS	Berlin	300.3	17.8	98.0	220.1
		<u>249,718.2</u>	<u>16,115.6</u>	<u>190,327.7</u>	<u>75,506.0</u>

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding
		2018 € (1000)	2018 € (1000)	2018 € (1000)	2018 € (1000)
Fraunhofer Group for Innovation Research – INNOVATION					
Center for International Management and Knowledge Economy IMW	Leipzig	6560.7	438.7	4164.3	2835.1
Industrial Engineering IAO	Stuttgart	34,428.6	979.7	28,786.4	6621.9
Information Center for Planning and Building IRB	Stuttgart	7740.0	106.9	2633.2	5213.8
Systems and Innovation Research ISI	Karlsruhe	26,232.0	330.1	21,068.0	5494.1
Technological Trend Analysis INT	Euskirchen	<u>2213.7</u>	<u>66.4</u>	<u>1764.6</u>	<u>515.5</u>
		<u>77,174.9</u>	<u>1921.9</u>	<u>58,416.5</u>	<u>20,680.3</u>
Fraunhofer Group for Life Sciences					
Biomedical Engineering IBMT Cell Therapy and Immunology IZI	Sulzbach Leipzig, Potsdam-Golm	15,632.8 37,529.3	1260.4 2699.8	13,630.9 29,118.8	3262.3 11,110.2
Interfacial Engineering and Biotechnology IGB	Stuttgart, Leuna	24,844.8	1600.5	16,117.2	10,328.2
Marine Biotechnology and Cell Technology EMB	Lübeck	2964.9	21.9	1902.6	1084.2
Molecular Biology and Applied Ecology IME	Aachen, Schmallenberg	41,149.8	3520.8	33,437.7	11,232.9
Process Engineering and Packaging IVV	Freising, Dresden	22,352.3	1310.5	17,609.3	6053.5
Toxicology and Experimental Medicine ITEM	Hannover, Braunschweig, Regensburg	<u>30,345.0</u>	<u>2267.0</u>	<u>22,375.1</u>	<u>10,236.9</u>
		<u>174,819.0</u>	<u>12,680.9</u>	<u>134,191.6</u>	<u>53,308.3</u>

**Performance statement for
individual Fraunhofer entities**

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding
		2018 € (1000)	2018 € (1000)	2018 € (1000)	2018 € (1000)
Fraunhofer Group for Light & Surfaces					
Applied Optics and Precision Engineering IOF	Jena	31,899.2	5664.1	25,558.0	12,005.3
Laser Technology ILT	Aachen	38,392.9	6139.0	32,124.4	12,407.5
Material and Beam Technology IWS	Dresden	31,234.8	2595.4	24,879.4	8950.8
Organic Electronics, Electron Beam and Plasma Technology FEP	Dresden	25,074.5	1767.6	19,325.9	7516.2
Physical Measurement Techniques IPM	Freiburg	18,262.5	1311.7	13,650.7	5923.5
Surface Engineering and Thin Films IST	Braunschweig	<u>11,934.6</u>	<u>310.5</u>	<u>7597.9</u>	<u>4647.3</u>
		<u>156,798.5</u>	<u>17,788.4</u>	<u>123,136.3</u>	<u>51,450.6</u>
Fraunhofer Group for Microelectronics					
Applied Solid State Physics IAF Electronic Nano Systems	Freiburg	13,288.8	3382.1	11,547.8	5123.1
ENAS	Chemnitz	13,831.2	1703.6	10,362.7	5172.1
High Frequency Physics and Radar Techniques FHR	Wachtberg	16,603.7	438.9	14,109.4	2933.1
Integrated Circuits IIS	Erlangen, Nürnberg, Dresden	175,118.3	5784.0	141,763.2	39,139.1
Integrated Systems and Device Technology IISB	Erlangen	25,588.8	1256.7	21,174.0	5671.5
Microelectronic Circuits and Systems IMS	Duisburg	32,125.1	1993.7	25,208.3	8910.5
Microsystems and Solid State Technologies EMFT	München	14,699.8	600.2	11,078.8	4221.2
Photonic Microsystems IPMS	Dresden	40,237.8	2354.4	30,045.7	12,546.5
Reliability and Microintegration IZM	Berlin, Dresden	33,675.5	2307.8	28,155.0	7828.3
Silicon Technology ISIT	Itzehoe	24,000.5	815.4	17,386.5	7429.4
Telecommunications, Heinrich-Hertz-Institut, HHI	Berlin, Goslar	52,628.7	4266.3	41,711.3	15,183.7
Central office – Research Fab Microelectronics Germany (FMD)	Berlin	<u>1255.7</u>	<u>77.9</u>	<u>825.6</u>	<u>508.0</u>
		<u>443,053.8</u>	<u>24,981.0</u>	<u>353,368.3</u>	<u>114,666.4</u>

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding
		2018 € (1000)	2018 € (1000)	2018 € (1000)	2018 € (1000)
Fraunhofer Group for Production					
Additive Manufacturing Technologies IAPT	Hamburg	9030.7	1088.0	5701.1	4417.7
Casting, Composite and Processing Technology IGCV	Augsburg, Garching b. München	14,122.5	3149.0	14,210.2	3061.3
Environmental, Safety and Energy Technology UMSICHT	Oberhausen, Sulzbach-Rosenberg	39,933.2	2276.8	30,812.6	11,397.4
Factory Operation and Automation IFF	Magdeburg	20,354.0	985.3	15,810.9	5528.3
Large Structures in Production Engineering IGP	Rostock	8439.8	262.3	6943.1	1759.0
Machine Tools and Forming Technology IWU	Chemnitz	41,707.2	4784.8	32,476.5	14,015.5
Manufacturing Engineering and Automation IPA	Stuttgart	63,097.6	5960.0	54,167.4	14,890.2
Material Flow and Logistics IML	Dortmund, Hamburg	30,782.7	1018.2	24,116.0	7684.9
Mechatronic Systems Design IEM	Paderborn	9822.6	930.4	8472.2	2280.9
Production Systems and Design Technology IPK	Berlin	19,671.0	1647.7	14,609.0	6709.6
Production Technology IPT	Aachen	<u>29,958.4</u>	<u>1546.5</u>	<u>21,942.1</u>	<u>9562.7</u>
		<u>286,919.5</u>	<u>23,649.1</u>	<u>229,261.1</u>	<u>81,307.6</u>
Fraunhofer Group for Defense and Security VVS¹					
Applied Solid State Physics IAF	Freiburg	15,585.7	1210.8	7558.8	9237.6
Chemical Technology ICT, Department of Energetic Materials	Pfanztal	14,659.8	763.7	4504.4	10,919.0
Communication, Information Processing and Ergonomics FKIE	Wachtberg	26,927.1	1864.1	15,540.2	13,251.1
High Frequency Physics and Radar Techniques FHR	Wachtberg	16,584.3	2691.0	7633.5	11,641.8
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	16,325.2	1382.2	7017.1	10,690.3
Optronics, System Technologies and Image Exploitation IOSB, Ettlingen branch	Ettlingen	20,333.5	1654.5	14,974.2	7013.8
Technological Trend Analysis INT	Euskirchen	<u>7295.7</u>	<u>495.4</u>	<u>2444.2</u>	<u>5346.8</u>
		<u>117,711.2</u>	<u>10,061.6</u>	<u>59,672.4</u>	<u>68,100.4</u>

1 Not including contract research activities.

**Performance statement for
individual Fraunhofer entities**

Fraunhofer Institute/ Research Institution for		Expenses		Income	
		Operating expenses	Capital expenditure	From external sources	Base funding
		2018 € (1000)	2018 € (1000)	2018 € (1000)	2018 € (1000)
Fraunhofer Group for Materials and Components – MATERIALS					
Applied Polymer Research IAP	Potsdam-Golm	22,470.2	1993.5	15,885.0	8578.7
Building Physics IBP	Stuttgart, Holzkirchen	25,187.8	1106.2	17,730.4	8563.6
Ceramic Technologies and Systems IKTS	Dresden, Hermsdorf	54,896.5	5747.6	43,414.6	17,229.5
Chemical Technology ICT, Polymer Engineering Department	Pfintzal, Karlsruhe	25,635.9	2117.3	20,667.3	7085.8
Energy Economics and Energy System Technology IEE	Kassel	24,204.7	1431.4	21,091.1	4545.0
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	7478.3	1519.7	5602.7	3395.3
Manufacturing Technology and Advanced Materials IFAM	Bremen, Dresden, Stade	48,250.6	3972.2	40,108.1	12,114.8
Mechanics of Materials IWM	Freiburg	21,175.5	2590.7	13,865.1	9901.0
Microengineering and Microsystems IMM	Mainz	11,795.7	611.9	7620.6	4787.0
Microstructure of Materials and Systems IMWS	Halle	22,823.8	933.2	17,693.8	6063.2
Nondestructive Testing IZFP	Saarbrücken	14,107.9	894.4	9601.9	5400.5
Silicate Research ISC	Würzburg, Bronnbach, Garching b. München, Bayreuth	33,142.1	1387.9	24,255.4	10,274.6
Solar Energy Systems ISE	Freiburg, Halle	84,583.7	10,908.7	82,396.0	13,096.3
Structural Durability and System Reliability LBF	Darmstadt	28,810.0	3376.0	20,695.3	11,490.7
Wind Energy Systems IWES	Bremerhaven, Kassel	21,898.4	5789.4	25,279.2	2408.7
Wood Research, Wilhelm-Klauditz-Institut, WKI	Braunschweig	15,809.5	2665.9	13,452.9	5022.5
		462,270.6	47,046.0	379,359.4	129,957.2
Centrally managed entities					
Fraunhofer headquarters	München	29,077.3	2272.1	5025.3	26,324.2
Institute Center Birlinghoven	Sankt Augustin	454.3	129.4	58.7	524.9
Institute Center Stuttgart	Stuttgart	391.8	457.9	8.5	841.2
General overhead costs		107,715.4	32,557.2	13,054.5	127,218.2
Major infrastructure capital expenditure			255,049.4	131,175.6	123,873.8
		137,638.8	290,466.1	149,322.5	278,782.3
Performance statement		2,106,104.4	444,710.5	1,677,055.9	873,759.1
Total business volume (cash basis)		2,550,814.9			

EXCERPTS FROM THE NOTES TO THE FINANCIAL STATEMENTS 2018

I. General disclosures

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, 2018 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	Presentation of annual accounts of the Fraunhofer-Gesellschaft
	Income statement		
Balance sheet	Reconciliation between income statement and performance statement		
	Performance statement		
Management report	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	

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.

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 3.21 percent was used in the calculation in accordance with Section 253 (2) of the German Commercial Code (HGB), along with the 2018 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 2018, 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, 2018, the income statement for the financial year 2018 and the full notes to the 2018 financial statements and the management report 2018.

CONVENIENCE TRANSLATION OF THE GERMAN INDEPENDENT AUDITOR'S REPORT

Note: This is a convenience translation of the German original.
Solely the original text in German language is authoritative.

INDEPENDENT AUDITOR'S REPORT

To the Fraunhofer-Gesellschaft zur Förderung der
angewandten Forschung e. V., Munich

Audit Opinions

We have audited the annual financial statements of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich, which comprise the balance sheet as at December 31, 2018, and the statement of profit and loss for the financial year from January 1, 2018 to December 31, 2018 and notes to the financial statements, including the presentation of the recognition and measurement policies. In addition, we have audited the management report of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich for the financial year from January 1, 2018 to December 31, 2018.

In our opinion, on the basis of the knowledge obtained in the audit,

- the accompanying annual financial statements comply, in all material respects, with the requirements of German commercial law applicable to business corporations and give a true and fair view of the assets, liabilities and financial position of the Company as at December 31, 2018 and of its financial performance for the financial year from January 1, 2018 to December 31, 2018 in compliance with German Legally Required Accounting Principles, and
- the accompanying management report as a whole provides an appropriate view of the Company's position. In all material respects, this management report is consistent with the annual financial statements, complies with German legal requirements and appropriately presents the opportunities and risks of future development.

Pursuant to § 322 Abs. 3 sentence 1 HGB [German Commercial Code], we declare that our audit has not led to any reservations relating to the legal compliance of the annual financial statements and of the management report.

Basis for the Audit Opinions

We conducted our audit of the annual financial statements and of the management report in accordance with § 317 HGB and in compliance with German Generally Accepted Standards for Financial Statement Audits promulgated by the Institut der Wirtschaftsprüfer [Institute of Public Auditors in Germany] (IDW). Our responsibilities under those requirements and principles are further described in the “Auditor’s Responsibilities for the Audit of the Annual Financial Statements and of the Management Report” section of our auditor’s report. We are independent of the Company in accordance with the requirements of German commercial and professional law, and we have fulfilled our other German professional responsibilities in accordance with these requirements. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinions on the annual financial statements and on the management report.

Responsibilities of the Executive Directors and the Senate for the Annual Financial Statements and the Management Report

The executive directors are responsible for the preparation of the annual financial statements that comply, in all material respects, with the requirements of German commercial law applicable to business corporations, and that the annual financial statements give a true and fair view of the assets, liabilities, financial position and financial performance of the Company in compliance with German Legally Required Accounting Principles. In addition, the executive directors are responsible for such internal control as they, in accordance with German Legally Required Accounting Principles, have determined necessary to enable the preparation of annual financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the annual financial statements, the executive directors are responsible for assessing the Company’s ability to continue as a going concern. They also have the responsibility for disclosing, as applicable, matters related to going concern. In addition, they are responsible for financial reporting based on the going concern basis of accounting, provided no actual or legal circumstances conflict therewith.

Furthermore, the executive directors are responsible for the preparation of the management report that as a whole provides an appropriate view of the Company’s position and is, in all material respects, consistent with the annual financial statements, complies with German legal requirements, and appropriately presents the opportunities and risks of future development. In addition, the executive directors are responsible for such arrangements and measures (systems) as they have considered necessary to enable the preparation of a management report that is in accordance with the applicable German legal requirements, and to be able to provide sufficient appropriate evidence for the assertions in the management report.

The senate decides on the annual accounts to be submitted to the general assembly meeting.

Auditor's Responsibilities for the Audit of the Annual Financial Statements and of the Management Report

Our objectives are to obtain reasonable assurance about whether the annual financial statements as a whole are free from material misstatement, whether due to fraud or error, and whether the management report as a whole provides an appropriate view of the Company's position and, in all material respects, is consistent with the annual financial statements and the knowledge obtained in the audit, complies with the German legal requirements and appropriately presents the opportunities and risks of future development, as well as to issue an auditor's report that includes our audit opinions on the annual financial statements and on the management report.

Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with § 317 HGB and in compliance with German Generally Accepted Standards for Financial Statement Audits promulgated by the Institut der Wirtschaftsprüfer (IDW) will always detect a material misstatement. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these annual financial statements and this management report.

We exercise professional judgment and maintain professional skepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the annual financial statements and of the management report, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our audit opinions. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal controls.
- Obtain an understanding of internal control relevant to the audit of the annual financial statements and of arrangements and measures (systems) relevant to the audit of the management report in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an audit opinion on the effectiveness of these systems of the Company.
- Evaluate the appropriateness of accounting policies used by the executive directors and the reasonableness of estimates made by the executive directors and related disclosures.
- Conclude on the appropriateness of the executive directors' use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Company's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in the auditor's report to the related disclosures in the annual financial statements and in the management report or, if

such disclosures are inadequate, to modify our respective audit opinions. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the Company to cease to be able to continue as a going concern.

- Evaluate the overall presentation, structure and content of the annual financial statements, including the disclosures, and whether the annual financial statements present the underlying transactions and events in a manner that the annual financial statements give a true and fair view of the assets, liabilities, financial position and financial performance of the Company in compliance with German Legally Required Accounting Principles.
- Evaluate the consistency of the management report with the annual financial statements, its conformity with law, and the view of the Company's position it provides.
- Perform audit procedures on the prospective information presented by the executive directors in the management report. On the basis of sufficient appropriate audit evidence we evaluate, in particular, the significant assumptions used by the executive directors as a basis for the prospective information, and evaluate the proper derivation of the prospective information from these assumptions. We do not express a separate audit opinion on the prospective information and on the assumptions used as a basis. There is a substantial unavoidable risk that future events will differ materially from the prospective information.

We communicate with those charged with governance regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

Nuremberg, March 22, 2019

Rödl & Partner GmbH
Wirtschaftsprüfungsgesellschaft, Steuerberatungsgesellschaft

signed Vogel
Wirtschaftsprüfer

signed Hahn
Wirtschaftsprüfer

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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

MEMBERS, CONSTITUENT BODIES,
COMMITTEES

FRAUNHOFER GROUPS

FRAUNHOFER ALLIANCES

FURTHER INITIATIVES AND
RESEARCH INFRASTRUCTURES

ADDRESSES IN GERMANY

INTERNATIONAL ADDRESSES

EDITORIAL NOTES

A person is kneeling on the floor of a large industrial facility, possibly a factory or research center. They are wearing a dark shirt and jeans, and are looking at a device or document in their hands. A black bag is on the floor next to them. The background shows large industrial machines with glass panels and metal frames. The lighting is bright, and the overall atmosphere is one of a modern, high-tech industrial environment. The image has a purple and red color overlay.



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Industrial Engineering

FESTO

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.

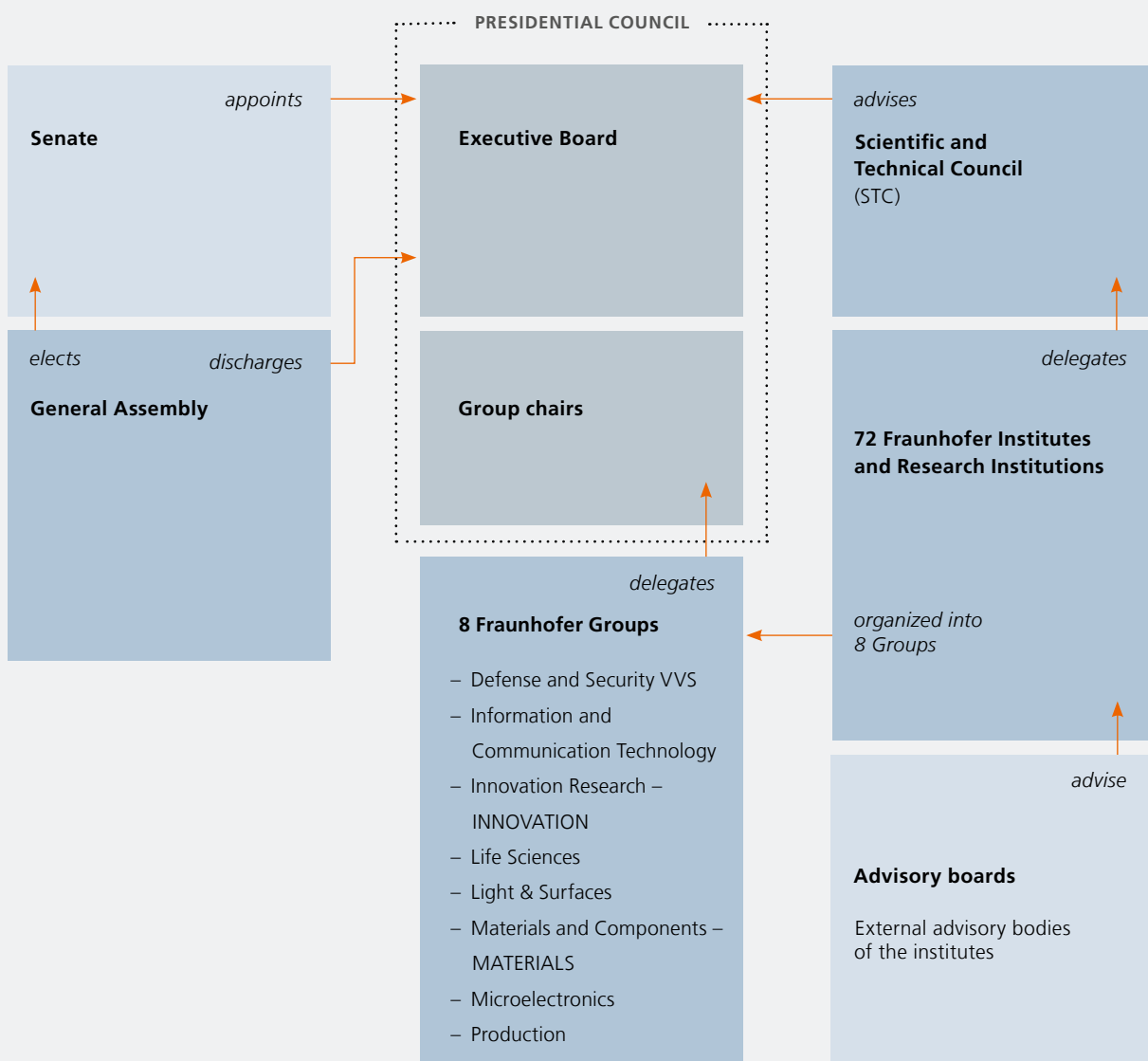
The **Senate** has around 30 members, comprising eminent figures from the worlds of science, business and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The Senate's duties include appointing members of the Executive Board, 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 advisory 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 1185 members, comprising 218 ordinary members, 958 official members, 2 honorary senators and 9 honorary members. Some members have multiple functions.

Honorary members

- Dr.-Ing. Peter Draheim
- Dr. Alfred Hauff
- 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 Walzl
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
- Kerstin Grosse
Chair of the 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
- Pär Malmhagen
President of Tower International Inc.
- Hildegard Müller
Chief Operating Officer Grid and Infrastructure, innogy SE
- Prof. Dr.-Ing. E. h. Hans J. Naumann
Chairman of the Board, 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 Trefffeldt
- 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

- State secretary Uwe Gaul
Saxon State Ministry of Science and the Arts
- State secretary Dr. Ulrike Gutheil
Brandenburg State Ministry of Science, Research and Cultural Affairs
- 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)
- MinDirig Ralf Schnurr
German Federal Ministry of Defence (BMVg)
- State secretary Sebastian Schröder
Ministry of Education, Science and Culture of Mecklenburg-Western Pomerania

Members delegated by the Scientific and Technical Council (STC)

- Prof. Dr. rer. nat. habil. Andreas Tünnermann
Chair of the Scientific and Technical Council, Director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF

- Dipl.-Ing. Stefan Schmidt
Deputy chair of the Scientific and Technical Council, Fraunhofer Institute for Material Flow and Logistics IML
- Prof. Dr. Peter Gumbsch
Director of the Fraunhofer Institute for Mechanics of Materials IWM

Honorary senators

- Prof. Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Ekkehard D. Schulz
- Prof. em. Dr.-Ing. Prof. h. c. mult. Dr. h. c. mult. Dr.-Ing. E. h. Hans-Jürgen Warnecke †

Permanent guests

- Prof. Dr. Martina Brockmeier
Chair, German Council of Science and Humanities
- Prof. Dr. Pascale Ehrenfreund
Chair of the Executive Board, German Aerospace Center e.V. (DLR)
- State secretary Dr. Oliver Grundel
Ministry of Education, Science and Cultural Affairs of Schleswig-Holstein
- Dipl.-Ing. Wolfgang Lux
Deputy chair of the Fraunhofer-Gesellschaft general works council, Fraunhofer Institute for Manufacturing Engineering and Automation IPA

- State secretary Annette Storsberg
Ministry of Culture and Science of North Rhine-Westphalia
- Prof. Dr. Martin Stratmann
President of the Max Planck Society for the Advancement of Science e.V.
- Dipl.-Ing. Dominik Toussaint
Chair of the Fraunhofer-Gesellschaft general works council, Fraunhofer Institute for Systems and Innovation Research ISI
- Minister of State Prof. Dr. Konrad Wolf
Ministry of Science, Education and Culture of Rhineland-Palatinate

Advisory boards

In total, the advisory boards of the institutes consist of 849 members, some of whom hold seats on the advisory boards of more than one institute.

Scientific and Technical Council (STC)

The Scientific and Technical Council has 150 members, 85 of whom are delegated institute directors or senior managers,

while 65 are elected representatives of the scientific and technical staff of each institute.

Chair of the Scientific and Technical Council:

- Prof. Dr. rer. nat. habil. Andreas Tünnermann
Director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF

Presidential Council

The Presidential Council of the Fraunhofer-Gesellschaft is made up of the members of the Executive Board and the chairs of the eight Fraunhofer Groups, named below:

- Prof. Dr.-Ing. Prof. E. h. Wilhelm Bauer
Fraunhofer Institute for Industrial Engineering IAO
- Prof. Dr. techn. Dieter W. Fellner
Fraunhofer Institute for Computer Graphics Research IGD
- Prof. Dr.-Ing. Dipl.-Phys. Hubert Lakner
Fraunhofer Institute for Photonic Microsystems IPMS
- Prof. Dr. Horst-Christian Langowski
Fraunhofer Institute for Process Engineering and Packaging IVV

- Prof. Dr. rer. nat. Reinhart Poprawe
Fraunhofer Institute for Laser Technology ILT
- Prof. Dr.-Ing. habil. Prof. E. h. Dr. h. c. mult. Michael Schenk
Fraunhofer Institute for Factory Operation and Automation IFF
- Prof. Dr. Ralf B. Wehrspohn
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Listed information valid as at January 31, 2019

FRAUNHOFER GROUPS

The Fraunhofer Groups are organizational units in which institutes and research institutions specializing in related areas of technology have joined together to coordinate their activities and present a single face to the market. They also help to formulate the Fraunhofer-Gesellschaft's business policy and to implement its working methods and funding model.

Fraunhofer Group for Defense and Security VVS
www.vvs.fraunhofer.de

Fraunhofer ICT Group
www.iuk.fraunhofer.de

Fraunhofer Group for Innovation Research – INNOVATION
www.innovationsforschung.fraunhofer.de

Fraunhofer Group for Life Sciences
www.lifesciences.fraunhofer.de

Fraunhofer Group for Light & Surfaces
www.light-and-surfaces.fraunhofer.de

Fraunhofer Group for Materials and Components –
MATERIALS
www.materials.fraunhofer.de

Fraunhofer Group for Microelectronics
www.mikroelektronik.fraunhofer.de

Fraunhofer Group for Production
www.produktion.fraunhofer.de

FRAUNHOFER ALLIANCES

Interdisciplinary alliances have been established between Fraunhofer Institutes or individual research departments to enable them to jointly develop and market solutions for specific business sectors.

www.fraunhofer.de/de/institute/institute-einrichtungen-deutschland/fraunhofer-allianzen

- Fraunhofer Adaptronics Alliance
- Fraunhofer Additive Manufacturing Alliance
- Fraunhofer AdvanCer Alliance
- Fraunhofer Ambient Assisted Living Alliance AAL
- Fraunhofer AutoMOBILE Production Alliance
- Fraunhofer Battery Alliance
- Fraunhofer Big Data and Artificial Intelligence Alliance
- Fraunhofer Building Innovation Alliance
- Fraunhofer Cleaning Technology Alliance
- Fraunhofer Cloud Computing Alliance
- Fraunhofer Digital Media Alliance
- Fraunhofer Embedded Systems Alliance
- Fraunhofer Energy Alliance
- Fraunhofer Food Chain Management Alliance
- Fraunhofer Lightweight Design Alliance
- Fraunhofer Nanotechnology Alliance
- Fraunhofer Photocatalysis Alliance
- Fraunhofer Polymer Surfaces Alliance POLO®
- Fraunhofer Simulation Alliance
- Fraunhofer Space Alliance
- Fraunhofer Technical Textiles Alliance
- Fraunhofer Traffic and Transportation Alliance
- Fraunhofer Vision Alliance
- Fraunhofer Water Systems Alliance (SysWasser)

FURTHER INITIATIVES AND RESEARCH INFRASTRUCTURES

Key Strategic Initiatives (KSIs)

The Fraunhofer-Gesellschaft has charted a roadmap for its research activities known as the Fraunhofer 2022 Agenda, which includes seven areas of strategic importance for industry and society (Key Strategic Initiatives) that pool the expertise of the Fraunhofer Institutes.

www.fraunhofer.de/de/forschung/prioritaere-strategische-initiativen

- Battery cell production
- Biological transformation
- Cognitive systems, artificial intelligence and data sovereignty
- Public security
- Programmable materials
- Quantum technology
- Translational medicine

Fraunhofer Clusters of Excellence

In a multidisciplinary research program, teams from several Fraunhofer Institutes collaborate in six Fraunhofer Clusters of Excellence, which in organizational terms function like virtual platforms with agile structures.

- Advanced Photon Sources – Ultrashort-pulse laser systems offering unprecedented high power output
- Cognitive Internet Technologies – Key technologies for the cognitive web. With the research centers Machine Learning, IoT-COMMs, Data Spaces
- Immune-Mediated Diseases – Personalized therapy and diagnostics for autoimmune pathologies and immune dysregulation
- Programmable Materials – Materials with reversible functionalities, which could replace sensor-actuator systems
- Circular Plastics Economy – Routes to a knowledge-based plastics recycling strategy with socioeconomic benefits
- Integrated Energy Systems – Creation of an energy system and market capable of dealing with a greater proportion of renewable energy sources with variable output

Lighthouse projects

With its lighthouse projects, the Fraunhofer-Gesellschaft sets strategic priorities in pre-competitive research. By pooling their expertise and involving industrial partners at an early stage, the Fraunhofer Institutes involved in the projects aim to turn original scientific ideas into marketable products as quickly as possible.

www.fraunhofer.de/de/forschung/fraunhofer-initiativen/fraunhofer-leitprojekte

Current lighthouse projects

- COGNAC – Cognitive Agriculture
- Go Beyond 4.0 – Digital Manufacturing – Innovative Integration of Digital Printing and Laser Processes for Mass Customization
- EVOLOPRO – Evolutionary Self-adaptation of Complex Production Processes and Products
- ML4P – Machine Learning for Production
- MED²ICIN – Digital patient model as a basis for personalised and cost-optimised treatment
- futureAM – Next Generation Additive Manufacturing
- QUILT – Quantum Methods for Advanced Imaging Solutions
- eHarsh – Sensor Systems for Extremely Harsh Environments
- ZEPOWEL – Towards Zero Power Electronics
- Combustion Engines for Tomorrow's Mobility – New Drive Systems, Fuels and AI

Completed lighthouse projects

- Electromobility – innovative technologies and components for hybrid and electric vehicles
- Critical Rare Earths – Efficient use of strategic high-tech metals
- E³ Production – Paradigm shift in production technology: away from maximizing profit from minimum capital investment toward maximizing added value from minimum resources
- Electricity as a Raw Material – Electrochemical processes for fluctuating energy and raw materials systems
- Theranostic Implants – Approval-relevant development of key technologies for medicine
- Cell-Free Bioproduction – Developing an industrial process for cell-free protein production

Further initiatives and research infrastructures

Further initiatives

Data sovereignty with Industrial Data Space

The Industrial Data Space is a Fraunhofer initiative that has meanwhile gained wide international support. Its aim is to create a secure repository for data belonging to companies of all sizes operating in different sectors of industry while giving them full sovereignty over the use of the stored data. www.fraunhofer.de/de/forschung/fraunhofer-initiativen/industrial-data-space

Morgenstadt Innovation Network – Developing ideas to improve the quality of life in the city of tomorrow

Through its “Morgenstadt” initiative, the Fraunhofer-Gesellschaft is supporting the German federal government in implementing an innovation project entitled “The CO₂-neutral, energy-efficient and climate-adapted city”, which is one of 10 projects selected to form part of the government’s High-Tech Strategy 2020. www.morgenstadt.de/

Project Centers

The interdisciplinary Fraunhofer Project Centers (FPCs) enable Fraunhofer Institutes to create local hubs focusing on specific areas of research. Their purpose is to establish a long-term relationship with other actors in the region, so as to develop a distinct profile for that region.

Lightweight Construction and Electromobility, Wolfsburg
www.hybridleichtbau.fraunhofer.de

Microelectronic and Optical Systems for Biomedicine, Erfurt
www.ipms.fraunhofer.de/de/services/project-hub-erfurt

Project Center for Energy Storage and Management Systems
ZEISS, Braunschweig

Collaborations

Research Fab Microelectronics Germany (FMD)

To reinforce the position of Europe’s semiconductor and electronics industry in the face of global competition, 11 member institutes of the Fraunhofer Group for Microelectronics are collaborating with 2 institutes from the Leibniz Association in a jointly managed facility for microelectronics and nanoelectronics research. www.forschungsfabrik-mikroelektronik.de

Cybersecurity Training Lab

Fraunhofer’s further education initiative Cybersecurity Training Lab strengthens research-based skill development in the field of IT security. It is operated by the Fraunhofer Academy in cooperation with select top-ranking universities of applied sciences. The topics covered extend from Industrie 4.0 to critical infrastructures and from software development to IT forensics.

Max Planck School of Photonics

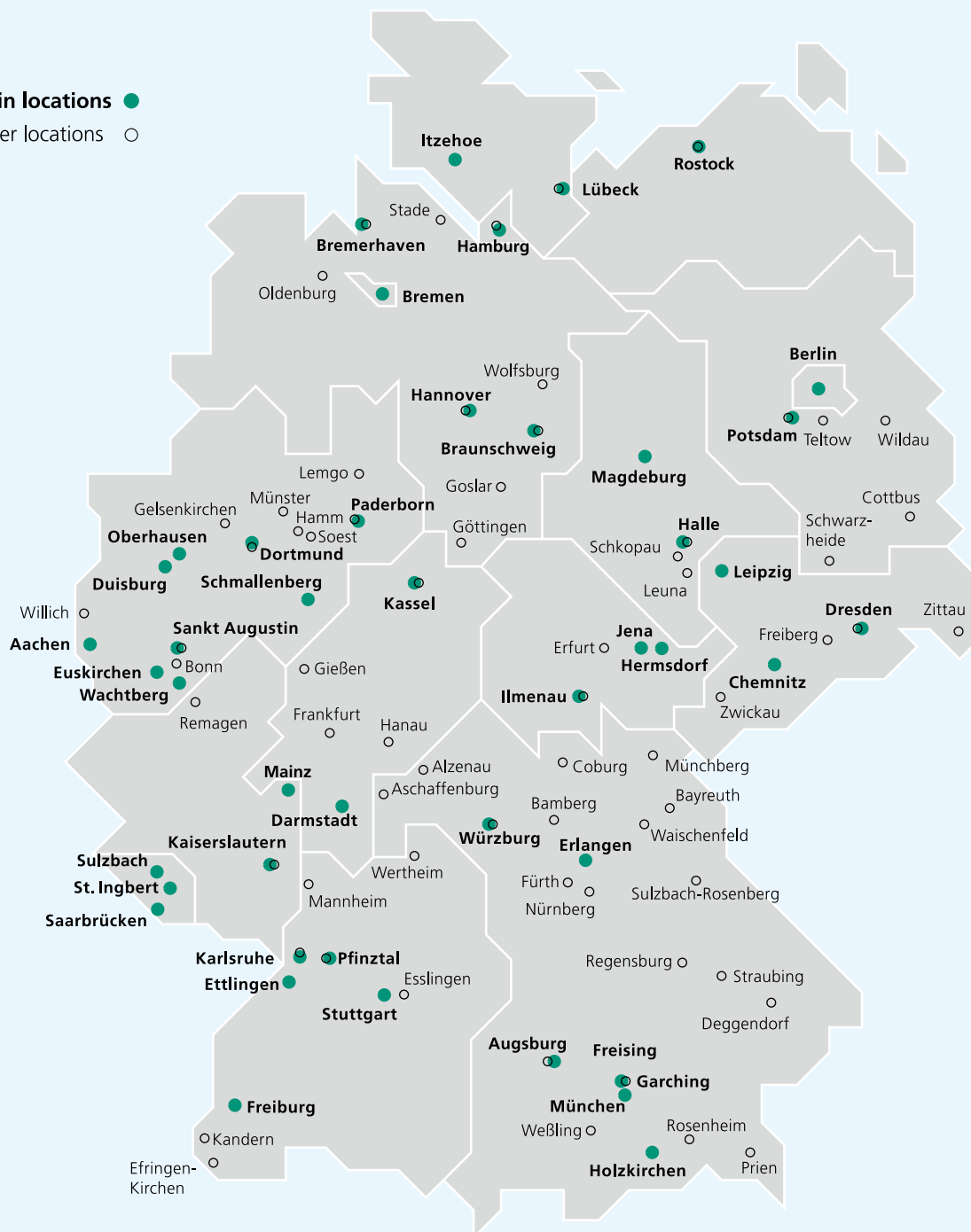
Sponsored by the German Federal Ministry of Education and Research (BMBWF), the Max Planck Schools initiative fosters an innovative brand of graduate education in Germany. The Max Planck School of Photonics is lead-managed by the Fraunhofer Institute for Optics and Precision Engineering IOF in Jena. www.maxplanckschools.de/photonics

High-Performance Centers

High-Performance Centers provide a common location for universities, other institutions of higher education and non-university research institutions to work together with enterprises and stakeholders from civil society to investigate specific research topics. At the centers, the partners jointly pursue the goal of boosting the economic impact and social benefits of research and development (R&D) through a more effective transfer infrastructure. The concept builds on a portfolio of excellent R&D projects, and has so far been implemented at 17 locations in 11 German states.

- Berlin Center for Digital Transformation
- High-Performance Center Chemical and Biosystems Technology, Halle-Leipzig region
- High-Performance Center Connected Adaptive Production, Aachen
- High-Performance Center DYNAFLEX: Dynamic and Flexible Processes for Energy and Raw Materials Transitions, Oberhausen
- High-Performance Center Electronic Systems, Erlangen
- High-Performance Center Functional Integration for Micro-/Nanoelectronics, Dresden-Chemnitz
- High-Performance Center Integration of Biological and Physical-Chemical Material Functions, Potsdam-Golm
- High-Performance Center Logistics and IT, Dortmund
- High-Performance Center Mass Personalization, Stuttgart
- High-Performance Center Mobility Systems, Karlsruhe
- High-Performance Center Photonics, Jena
- High-Performance Center Connected Secure Systems, München
- High-Performance Center Security and Privacy in the Digital World, Darmstadt
- High-Performance Center Simulation and Software-based Innovation, Kaiserslautern
- High-Performance Center Sustainability, Freiburg
- High-Performance Center Translational Biomedical Engineering, Hannover

Main locations ●
Other locations ○



ADDRESSES IN GERMANY

Fraunhofer-Gesellschaft

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

Postal address

Postfach 20 07 33
80007 München, Germany
Phone +49 89 1205-0
Fax +49 89 1205-7531
info@fraunhofer.de

Executive Board

President, Corporate Policy and Research Management,
Technology Marketing and Business Models:
Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult. Dr. h. c. mult.
Reimund Neugebauer

Address for visitors

Hansastraße 27c
80686 München, Germany

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

Controlling and Digital Business Processes:
Dipl.-Kfm. Andreas Meuer

Information on fields of research, links to all Fraunhofer
Institutes and Research Institutions, as well as to the
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www.fraunhofer.de

Historic

Fraunhofer Glassworks

Fraunhoferstraße 1
83671 Benediktbeuern
Germany



INTERNATIONAL ADDRESSES

Fraunhofer International

Contact in Germany

Fraunhofer-Gesellschaft
International Business Development
Thomas Dickert
Phone +49 89 1205-4700
Fax +49 89 1205-77-4700
thomas.dickert@zv.fraunhofer.de
Hansastraße 27c
80686 München, Germany

The Fraunhofer-Gesellschaft operates legally independent international Fraunhofer affiliates in Europe, North America, South America and Asia. In other regions, Fraunhofer Representative Offices and Fraunhofer Senior Advisors form a bridge to local markets worldwide. The Fraunhofer Office in Brussels serves as an interface between Fraunhofer and the institutions of the European Union. For specific contact addresses, please consult our website:

Contact in Brussels

Fraunhofer-Gesellschaft
Brussels Office
Mathias Rauch
Phone +32 2 50642-42
Fax +32 2 50642-49
mathias.rauch@zv.fraunhofer.de
Rue Royale 94
1000 Brussels, Belgium

www.fraunhofer.de

Editorial notes

Editorial team

Dr. Martin Thum (editor in chief)
Markus Jürgens (picture editor)

Editorial assistance

Eva Bachmann
Mandy Bartel
Helga Eisch-Hagenauer
Dorothee Höfter
Eva Rathgeber
Laura Rottensteiner
Tanja Schmutzer

Production

Silke Schneider
Jürgen Mosler

Design concept

Markus Jürgens
Silke Schneider

Layout

Kruse+Company

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Burton, Van Iersel & Whitney
GmbH, Munich

You can call up the addresses,
focal fields of research, and
contacts for all Fraunhofer
Institutes and Groups in English or
German on the Internet:

www.fraunhofer.de

Editorial address

Fraunhofer-Gesellschaft
Hansastraße 27c
80686 München, Germany
Dr. Martin Thum
Internal Communications
Phone +49 89 1205 1367
martin.thum@zv.fraunhofer.de

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