

ANNUAL REPORT 2019

OUR FUTURE MISSION: RESEARCH FOR
SUSTAINABLE VALUE CREATION

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft is the world's leading applied research organization. In focusing on key technologies for the future and their commercial exploitation by business and industry, Fraunhofer plays a pivotal role in the innovation process. Based in Germany, Fraunhofer is a pioneer and catalyst for groundbreaking developments and a model of scientific excellence. As a source of inspirational ideas and sustainable scientific and technological solutions, Fraunhofer provides science and industry with a vital base and helps shape society both now and in the future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work with partners from industry and government to turn novel ideas into innovative technologies, to coordinate and realize key research projects with a systematic relevance, and to strengthen the German and European economy with a commitment to value creation that is based on ethical values. International collaboration with outstanding research partners and companies from around the world brings Fraunhofer into direct contact with the key regions that drive scientific progress and economic development.

Founded in 1949, the Fraunhofer-Gesellschaft currently operates 74 institutes and research institutions throughout Germany. The majority of the organization's 28,000 employees are qualified scientists and engineers. They work with an annual research budget of 2.8 billion euros. Of this sum, 2.3 billion euros is generated through contract research. Around 70 percent of Fraunhofer's contract research revenue is derived from industry contracts and from publicly funded research projects.

The remaining 30 percent comes from the German federal and state governments in the form of base funding. This enables our institutes to work on solutions that are likely to become vital for industry and society in the coming years.

Applied research also has a knock-on effect that is felt way beyond the direct benefits to the customer. Our institutes boost industry's performance and efficiency, promote the acceptance of new technologies within society, and help train the future generation of scientists and engineers that the economy so urgently requires.

We have a highly motivated staff, working at the cutting edge of research. They are the key factor for our success as a scientific organization. Fraunhofer offers its researchers the opportunity to undertake independent, creative and, at the same time, targeted work. We provide our employees with a chance to develop the professional and personal skills that will enable them to take up positions of responsibility within Fraunhofer itself or at universities, in industry and in society. Students who work on projects at Fraunhofer Institutes have excellent career prospects in industry on account of the practical training they enjoy and the early experience they acquire of dealing with contract partners.

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

Figures as at January 2020
www.fraunhofer.de

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Ladies and gentlemen,

In 2019 – an anniversary year for the Fraunhofer-Gesellschaft – we once again returned an impressive performance, marked by new record figures. Our total business volume increased by 8 percent to 2.8 billion euros; contract research by 6 percent to 2.3 billion euros. At the root of our sustained success is the expertise and exceptional dedication of our 28,000 employees. Each day, they perform outstanding work at our 74 institutes and research institutions, be it in scientific, organizational or administrative areas. Let me take this opportunity, on behalf of the entire Executive Board, to thank them all!

The motto for our anniversary year was “70 years of Fraunhofer. 70 years of future. #WHATSNEXT”. Under this banner, we celebrated at home – with our institutes – and away – with our partners from business, politics and civil society. Our anniversary was an opportunity not only to review past successes but also to look ahead to the future and to set out our goals for Germany and Europe. It was an occasion to showcase the Fraunhofer-Gesellschaft as an innovative force, a strong partner and an agile player – one that is eager to seize new opportunities and to support business and politics in their endeavors to tackle key social and economic challenges.

As a leading research organization, Fraunhofer bears an ever-growing responsibility for developments in science, business, politics and society. It is a challenge we are happy to accept. We will therefore continue to do everything in our power to fulfill the standards this requires in terms of scientific excellence, ethical conduct and professional integrity. Our understanding of corporate responsibility rests on a set of principles that are subject to continuous review. At Fraunhofer, corporate responsibility means having an HR policy that meets our employees’ needs and offers them motivation. It means using resources in a way that is efficient and sustainable; and respecting and deepening ethical, social and environmental norms.

With respect to equal opportunities, we must strive to ensure we make better use of the huge potential offered by expert female researchers. In the face of fierce global competition, this is a pool of talent we cannot ignore. By the same token, as a scientific body committed to delivering research excellence, we cannot afford to dispense with the expertise of researchers from countries beyond Germany. Our goal is therefore to establish English as the second official language at Fraunhofer, thereby ensuring that we offer ideal conditions for these new members of our workforce.

A prime objective of our research is to facilitate the sustainable creation of value. It is a goal we pursue in a host of projects, such as our living laboratory for the generation, transport, storage and use of renewable hydrogen. Further examples include the recent establishment of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, which incorporates the International Geothermal Centre Bochum (GZB), and of the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS. Meanwhile, the Fraunhofer-Zukunftstiftung (Fraunhofer Future Foundation) will now focus on projects with a commitment to value creation that is based on ethical values, although commercial viability remains a key consideration. The current annual report includes a section devoted to the topic of ethics and responsibility in the field of applied research.

The aim of the Fraunhofer Digital project is to progressively digitalize and automate our business processes. This will enable us to create an extremely efficient system of administration. At the same time, it will mean that we can put our own data to work in increasingly connected and intelligent applications that give us the leverage to exploit further business and innovation potential. This project is vital for our future efficiency. In the future, we will have to hold our own in an extremely challenging environment, with increasingly rapid cycles of innovation and in global competition with large and ambitious economic regions.

Our dedication and our will to succeed will also guide us in the fight against the coronavirus. The Executive Board and the Presidential Council have resolved to launch a major program of action to confront these challenges and to boost our impact and power of innovation even in these times of crisis. By conducting precompetitive research in strategic areas, we will prepare the ground for a necessary surge in innovation. Our message to industry is therefore that Fraunhofer will continue to facilitate value creation and thereby secure prosperity.

Here, too, we will continue to pursue rational scientific inquiry and thereby help shape the future on behalf of Germany and Europe. Together with our customers, our partners and our entire workforce, we will do everything in our power to ensure that 2020 is also a resounding success!

Yours sincerely,

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

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft



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REPORT OF THE EXECUTIVE BOARD

THE EXECUTIVE BOARD

MANAGEMENT REPORT 2019

REPORT OF THE SENATE ON THE FINANCIAL YEAR 2019

INSIDE THE FRAUNHOFER SENATE

THE EXECUTIVE BOARD



Following senior roles in the mechanical engineering industry, Reimund Neugebauer established in 1991 what has since become the Fraunhofer Institute for Machine Tools and Forming Technology IWU. In his 21 years as director, the institute grew to become an international center for manufacturing engineering. Over this period, he served in parallel as director of the Institute for Machine Tools and Production Processes at Chemnitz University of Technology. Prof. Dr. Neugebauer is a member of numerous national and international academies and associations. He has served as president of the Fraunhofer-Gesellschaft since 2012.

Prof. Dr.-Ing. habil. Prof. E. h. Dr.-Ing. E. h. mult. Dr. h. c. mult.

Reimund Neugebauer

President of the Fraunhofer-Gesellschaft, Corporate Policy and Research Management



Andreas Meuer has occupied a variety of senior 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, Finances and Digitalization



After studying to become a lawyer, Alexander Kurz served as an executive and a board member at 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



Following a number of scientific posts both at home and abroad, Ralf Boris Wehrspohn was appointed professor of Microstructured Material Design at Martin-Luther-Universität Halle-Wittenberg in 2006. He was also director of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS for 13 years. Following a period as chair of the Fraunhofer Group for Materials and Components – MATERIALS, he was appointed to the Executive Board of the Fraunhofer-Gesellschaft in 2019.

Prof. Dr. rer. nat. habil.

Ralf Boris Wehrspohn

Executive Vice President, Technology Marketing and Business Models

MANAGEMENT REPORT 2019

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Fraunhofer-Gesellschaft – key data for 2019 (in € million)

	2018	2019	Change	
Total business volume	2551	2760	+209	+8%
Contract research	2168	2295	+127	+6%
Additional research funding	128	159	+31	+24%
Major infrastructure capital expenditure	255	306	+51	+20%
Business volume by budget	2551	2760	+209	+8%
Operating budget	2106	2279	+173	+8%
of which: personnel expenses	1362	1479	+117	+9%
of which: non-personnel expenses	698	769	+71	+10%
of which: transfer to reserves ¹	46	31	-15	-33%
Capital expenditure ²	445	481	+36	+8%
Project revenue	1677	1756	+79	+5%
Contract research	1486	1549	+63	+4%
of which: industrial revenue	723	724	+1	+0%
of which: public-sector project revenue ³	763	825	+62	+8%
Additional research funding	60	79	+19	+32%
Major infrastructure capital expenditure	131	128	-3	-2%
International project volume⁴	293	296	+3	+1%
Patent applications (number)	612	623	+11	+2%
Employees (number)	26,648	27,988	+1340	+5%

1 Special reserve for license-fee revenue.

2 Current capital expenditure for contract research, additional research funding, and major infrastructure capital expenditure.

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

4 Excludes license-fee revenue and revenue generated by legally independent international Fraunhofer affiliates through business with third parties (2019: €29 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. It carries out applied research and development for the benefit of industry and society. The organization's **fields of research** focus on people's needs: health, security, communication, mobility, energy, and the environment.

Together, the 74 Fraunhofer Institutes and Research Institutions in Germany employ around 28,000 people who generate an annual business volume of €2.8 billion. Contract research accounts for €2.3 billion of this total. Around 70 percent of Fraunhofer's **contract research** revenue is derived from contracts with industry and publicly funded research projects, while the German federal and state governments contribute around 30 percent in the form of base funding for precompetitive research.

At an organization-wide level, Fraunhofer identifies innovative areas of business and trending technologies with significant market potential and/or relevance to society and sets up **in-house research** programs to move them forward.

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

The seven **Fraunhofer Groups** are a way for Fraunhofer Institutes that conduct contract research in related areas of technology to coordinate their R&D strategies:

- Information and Communication Technology
- Innovation Research – INNOVATION
- Life Sciences
- Light & Surfaces
- Materials and Components – MATERIALS
- Microelectronics
- Production

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

In the **70 years** since the Fraunhofer-Gesellschaft was founded, the organization has grown from strength to strength on the back of its successful Fraunhofer funding model for applied research. The Fraunhofer-Gesellschaft has an undeniable impact, as confirmed by the many testimonials received from a long list of notable scientists, policy-makers and business-people during the anniversary-year events.

Creating opportunities through strategic initiatives

The Fraunhofer-Gesellschaft continues to pursue its strategy of quantitative **growth** without losing sight of quality. As the R&D portfolio grows in breadth and depth, there is an increasing need for structures to leverage synergies and avoid redundant efforts. In 2019, Fraunhofer created new instruments and processes at corporate level with this aim in mind. Similarly, the processes by which research findings are transferred to industry are being more closely interlinked.

The ten high-impact projects launched in 2018 as part of the **Fraunhofer 2022 Agenda** to promote excellence were reviewed in 2019 by the Executive Board and the Presidential Council. Completed projects such as the introduction of an international mobility program were removed from the agenda, while the goals of some other projects were modified, as in the case of “gender-appropriate excellent careers,” which now places a stronger emphasis on appointing more women as institute directors. At the same time, new projects were added to the agenda, including the establishment of skills-based alliances (see below). The projects that form part of the revised Fraunhofer 2022 Agenda are continually monitored by a foresight committee, the Future Commission, consisting of the members of the Fraunhofer Executive Board and eleven institute directors.

Our unique grasp of new technologies and excellent performance are currently based on the efforts of 74 Fraunhofer Institutes and Research Institutions. Combining these efforts into alliances formed by institutes with similar scientific expertise builds strong and internationally competitive centers of excellence and research portfolios. A standardized strategy planning process for the Fraunhofer Institutes has been in place for over 15 years, with the aim of strengthening each institute’s competitiveness. This process was comprehensively reformed for the second time in 2019, to take account of changes in the domestic and international markets and

implement best practices. The new process aligns research objectives more closely with the overlying strategy, permits both top-down and bottom-up approaches, and is compatible with Fraunhofer-wide business activities. This approach to strategy planning gives the Fraunhofer Groups greater scope to leverage synergies and use their resources efficiently, allowing them to follow their own, coordinated strategies for specific research topics.

Since 2015, the **High-Performance Centers** have proved their worth as part of the national research transfer infrastructure in Germany. In these centers, Fraunhofer Institutes work together with universities, non-university research institutions and industrial partners. They serve as platforms in the innovation ecosystem, using a wide range of routes to transfer knowledge on the basis of structured roadmaps for their specific region. All 16 High-Performance Centers were evaluated in 2019 and in all cases it was recommended that they should continue. An analysis of their results showed that, between them, the High-Performance Centers had generated €140 million in industrial revenue and led to more than 300 contracts being placed with Fraunhofer by small and medium-sized enterprises (SMEs).

In 2019, at the request of the German Federal Ministry of Education and Research (BMBF), Fraunhofer developed an outline concept for a new **Research Fab Battery Cells (FFB)**, to accelerate the transfer of new battery designs and innovative production methods to commercial use. The FFB forms part of a wider BMBF initiative in which funding for battery technology research will be distributed to a number of different competence centers and clusters in Germany. Fraunhofer is set to play an active role in setting up and operating this major project, for which the BMBF has earmarked a total of €500 million in funding. The state of North Rhine-Westphalia has agreed to provide a further €200 million for the construction of a building to house the new facility in Münster.

The Fraunhofer-Gesellschaft adapts its portfolio to the changing needs of industry and society by expanding or reorienting the focus of its institutes and by founding new institutes or research institutions. For example, 2019 saw the creation of the **Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG**. It resulted from the integration of the International Geothermal Centre Bochum (GZB) into the Fraunhofer-Gesellschaft, with the addition of two other locations, one in Cottbus focusing on energy infrastructures and one in Jülich focusing on sector coupling. These three locations form a bridge between the regions most affected by structural change in eastern and western Germany. One significant example of a change of thematic focus is the renaming of the former Fraunhofer Institute for Embedded Systems and Communication Technologies ESK, which now operates under the name of **Fraunhofer Institute for Cognitive Systems IKS**. The new focus of research at Fraunhofer IKS is security and safety aspects of artificial intelligence (“safe intelligence”).

Fraunhofer has also embraced the concept of **lead markets**, in which Fraunhofer addresses the research needs of specific sectors, aiming to boost their ability to compete on a global scale and achieve technological sovereignty in Germany and Europe. This is to be achieved in particular by refocusing the existing Fraunhofer Alliances, for instance by building up the capacity of the Fraunhofer Energy Alliance and of the Fraunhofer Mobility working group which forms part of the Fraunhofer Transport Alliance.

The **research transfer program**, launched in collaboration with the **Deutsche Forschungsgemeinschaft (DFG)** to support trilateral projects involving Fraunhofer Institutes, industrial partners and universities, successfully moved on to the actual project phase in 2019. It gives companies the opportunity to share in the latest basic research findings at an early stage and develop them into applications with the help of the Fraunhofer-Gesellschaft’s transfer experts. Each project runs for a maximum of three years, during which the partners work together to build a demonstrator or prototype.

Links between Fraunhofer and universities or universities of applied science were further expanded in 2019. In total, Fraunhofer employees provided around 8900 hours of tuition per week during semester time. Approximately three-quarters of these hours of tuition were delivered at universities, and one quarter at universities of applied science. At the beginning of 2018, Fraunhofer decided to introduce an SAP system consisting of an enterprise resource planning (ERP) module to manage essential business processes and a business intelligence (BI) module allowing information and data sources to be shared throughout the Fraunhofer dataspace. The main reason for this move was to bring the Fraunhofer-Gesellschaft’s existing IT structures into line with those in the “outside world,” thus enabling it to deal with the exponential growth in available data, interconnected systems, and IT-based collaboration with customers. The go-live date for its organization-wide introduction is early 2021.

Science policy framework

Through the person of its president, the Fraunhofer-Gesellschaft is represented in the German federal government's two most important advisory committees on research and innovation: the High-Tech Forum and the Innovation Dialog.

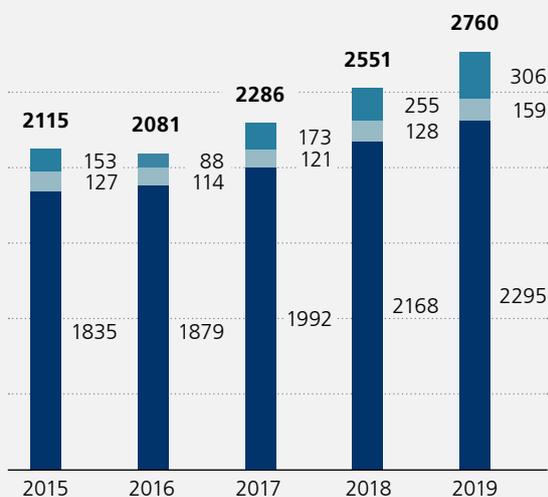
The **High-Tech Forum** has been chaired jointly by Professor Neugebauer and Christian Luft, state secretary at the German Federal Ministry of Education and Research (BMBF), since the beginning of 2019. This body is tasked with advising the government on how to implement and further develop its High-Tech Strategy 2025. The High-Tech Forum met three times in 2019 to discuss issues surrounding innovation policy, and published two discussion papers: one looks into possible ways of reaching the 3.5-percent target, i.e. increasing R&D spending to 3.5 percent of GDP, while the other deals with the topic of social innovation; its authors advocate that social innovation should be seen as complementary to technological innovation, and they have made proposals for funding relevant research. The resulting recommendations for action will be discussed by the round table of state secretaries. Representatives of the High-Tech Forum also attended an evening parliamentary session to answer questions directly posed by members of the Bundestag. Six key topics have been placed on the agenda for 2020: agility of the innovation system, future forms of value creation, sustainability within the innovation system, innovation and skills, biology and digitalization, and open science and innovation. The Fraunhofer-Gesellschaft's science policy department also provides support to the federal ministries with regard to governance of the missions with which the High-Tech Forum is entrusted in connection with the High-Tech Strategy 2025. In a parallel research project, the Fraunhofer Institute for Systems and Innovation Research ISI studies indicators to measure the success of these missions.

The **Innovation Dialog** is an independent group of government advisors consisting of high-ranking representatives of business, industry, science and society at large, who come together to discuss issues of relevance to future innovation policy. In January 2020, German Chancellor Angela Merkel and members of her cabinet met with the steering committee, of which Professor Neugebauer is a member, for the third Innovation Dialog in the 19th legislative period. The main topic of discussion was the innovation potential of second-generation quantum technologies, which could lead to a breakthrough in novel, disruptive applications such as quantum computing, quantum communication and quantum sensing. The agility of the innovation system was also discussed on the basis of the eponymous discussion paper. The next Innovation Dialog meeting is scheduled for June 2020 and will focus on innovations for a green deal. Professor Neugebauer and three other members of the steering committee have been entrusted with compiling material for this as-yet confidential case file.

Fraunhofer welcomes the promulgation of the German **Act on Tax Incentives for Research and Development (FZuIG)**. This puts an end to a debate that has been going on for more than a decade. The new law rightly ensures that funding for applied research benefits the contracting party. Fraunhofer has lobbied intensively from the start for a law that makes this possible. According to the provisions of the new law, which came into force on January 1, 2020, all commercial enterprises subject to corporation or income tax in Germany will be able to claim tax benefits not only for in-house R&D but also for research conducted under contract by external third parties. The new rules allow 60 percent of the amount paid to external research service providers to be recognized as eligible personnel costs. Companies can claim 25 percent of these eligible costs as a reduction in corporation tax. The maximum amount of eligible research costs is limited to €2 million per year per company. Consequently, the maximal achievable tax savings per company amount to €500,000 per year.

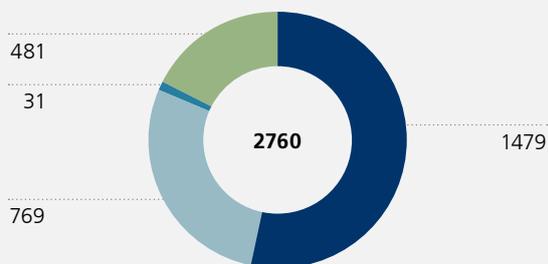
BUSINESS REPORT

Fraunhofer's total business volume in € million



- Major infrastructure capital expenditure
- Additional research funding
- Contract research

Total business volume 2019 by budget, in € million



- Personnel expenses
- Non-personnel expenses
- Transfer to reserves
- Capital expenditure

Total business volume

In business terms, 2019 was a successful year for Fraunhofer. The total business volume amounted to just short of €2.8 billion, having increased by a substantial 8 percent compared with the previous year. Contract research accounted for 83 percent of this sum, or around €2.3 billion, and represents the organization's core activity, around one third of which is financed by means of base funding provided by the federal and state governments. As of 2019, research of a long-term nature that falls outside the scope of this regular base funding is allocated to a new item, additional research funding, which amounted to €159 million in the reporting period. Major infrastructure capital expenditure amounted to €306 million. 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. 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 total, capital expenditure rose to €481 million, an increase of 8 percent. In 2019, the ratio of capital expenditure to total business volume was 18 percent, as in the previous year. The personnel expenses recognized in the operating budget rose by 9 percent to €1479 million, an increase that was due to workforce growth of 1340 employees (up 5.0 percent) and to a 3.1-percent average wage increase granted as of April 1, 2019 under the collective wage agreement for the public sector. At €769 million, non-personnel expenses were around 10 percent higher than in the previous year. Reserves increased by €31 million.

Contract research

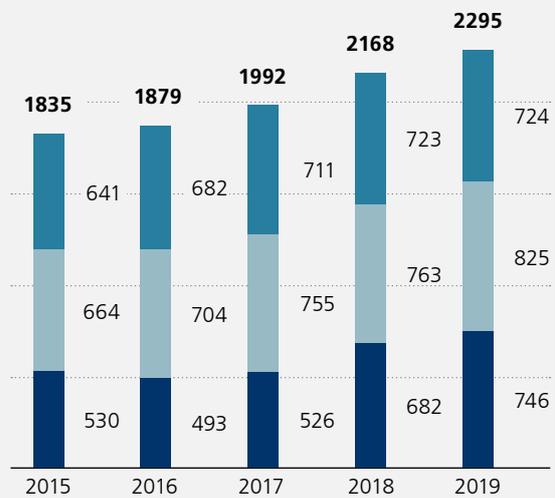
Contract research is the mainstay of Fraunhofer’s business activities and, based on the Fraunhofer funding model, consists of three areas each contributing around one third to the organization’s finances:

- Research directly contracted by industry
- Publicly funded research projects
- Precompetitive research funded with base funding

Budgeted expenditure for the contract research segment grew by 6 percent in 2019 to reach €2295 million, of which the operating budget accounted for €2142 million and capital expenditure for €153 million. The amount of base funding used to finance precompetitive research increased by 9 percent to €746 million. Base funding is provided by the BMBF and the state governments in a ratio of 90:10. New research institutions generally receive initial funding from their host state during their first five years. Industrial revenue, at €724 million, was on a par with the previous year. Revenue from contracts with industry increased by 1 percent to €617 million, while license-fee revenue decreased by 2 percent to €107 million.

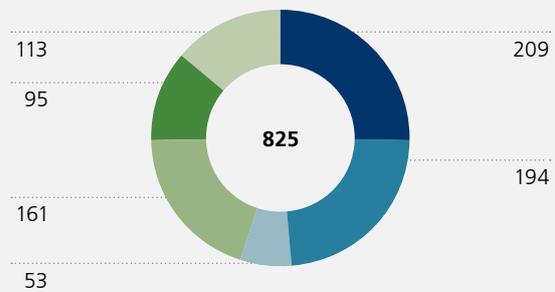
Revenue from publicly funded projects continued to increase significantly in 2019. Funding granted by the German Federal Ministry for Economic Affairs and Energy (BMWi) grew at a particularly high rate, increasing by 28 percent to €194 million. Revenue from projects funded by the German Federal Ministry of Education and Research (BMBF) increased by 7 percent to €209 million, while funding by individual states also increased by 7 percent, to €161 million. Revenue from other public sources totaled €113 million, and includes funding by foundations, universities and other institutions. EU revenue increased by 4 percent to €95 million. As a partner in the Horizon 2020 Research Framework Programme, Fraunhofer plays an active role in shaping the European Research Area and ranks third among participating research organizations in terms of research funding granted.

Revenue from contract research in € million



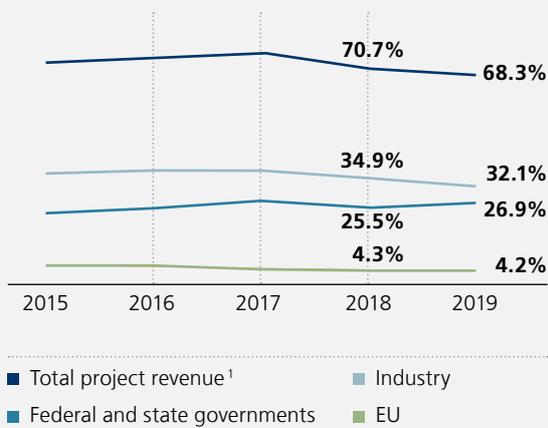
- Industrial revenue
- Revenue from publicly funded projects
- Base funding

Revenue from publicly funded projects in € million (2019)



- BMBF
- BMWi
- Other government agencies
- Federal states
- EU
- Other sources

Funding ratio in %



¹ Includes other sources of revenue, 2019: 5.1%.

International project volume in € million



The Fraunhofer-Gesellschaft's high **external funding ratio** is a unique feature of the organization's financial structure, and a key performance indicator in the world of contract research. It is calculated as the share of external funding in the operating budget, including imputed write-downs on investments (excluding initial funding for newly founded facilities and excluding changes in reserves.) Due to sustained strong organic growth, project revenue accounted for a steadily increasing share of the operating budget up until 2017, whereas the proportion covered by base funding has tended to decline. Thanks to an exceptional increase in base funding granted in 2017, with annual increments, and the strategic utilization of these financial resources, the funding mix returned as planned to the level foreseen by the Fraunhofer funding model. The proportion of the operating budget for contract research covered by external sources has remained above two-thirds, at 68.3 percent. The strongest increase was in revenue from the federal and state governments, which rose to a share of 26.9 percent. On the other hand, the share of industrial revenue in the overall budget decreased to 32.1 percent.

The consistently high international project volume is an indicator of Fraunhofer's **success in the global research market**. In 2019, revenue from international projects amounted to €296 million (excluding license-fee revenue) and represented 19 percent of total contract research project revenue. Some 32 percent of the international project volume came from EU-funded projects, 40 percent from customers and partners in Europe, and 28 percent from those outside Europe. The amount of project volume generated by customers and partners within Europe increased by 3 percent to €117 million, while that generated by customers and partners outside of Europe decreased slightly to €84 million. Switzerland, at €28 million, remained the largest market outside of Germany, followed by the USA (€26 million) and Austria (€20 million). The largest markets in Asia were China and Japan, with revenues of €18 million and €17 million respectively.

Additional research funding

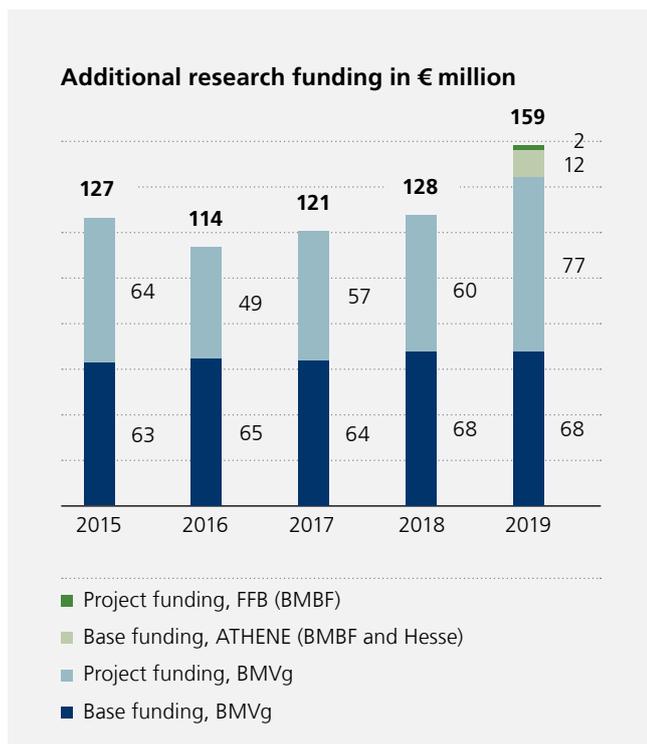
In 2019, alongside the established, separate funding route for defense research, additional research funding was obtained for the first time through the National Research Center for Applied Cybersecurity **ATHENE** and through the **Research Fab Battery Cells (FFB)**.

ATHENE is operated jointly by the Fraunhofer Institutes for Secure Information Technology SIT and for Computer Graphics Research IGD in collaboration with Technische Universität Darmstadt and Darmstadt University of Applied Sciences. Its research focuses on the protection of critical infrastructures such as power and transportation, and the security of IT systems. An interdisciplinary approach is applied, combining IT and engineering with legal and business aspects, psychology and ethics. **ATHENE** was launched in 2019 with an operating

budget of €12 million, funded by the BMBF and the state of Hesse in a ratio of 70:30.

An initial amount of €2 million was spent in 2019 on **setting up the FFB** (see Creating opportunities through strategic initiatives). This amount will increase substantially in the years to come.

Seven Fraunhofer Institutes address topics that fall within the sphere of interest of the German Federal Ministry of Defence (BMVg). These activities, for which the BMVg provides base funding and ongoing project funding, are grouped together under **defense research**. The objective of these R&D activities is to provide people, infrastructures and the environment with the best possible protection against potential security threats of a military, technological, terrorist or criminal nature or resulting from natural disasters. Revenue from defense research grew by 13 percent in 2019 to €145 million, mainly as a result of the substantial, 28-percent increase in project funding to €77 million. At €68 million, the amount required from base funding was on a level with the previous year.



Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises building projects and the purchase of scientific instruments and furniture to equip new facilities. This item also includes capital expenditure in connection with the Research Fab Micro-electronics Germany (FMD), a longer-term project involving 11 Fraunhofer Institutes and 2 Leibniz Institutes. Total major infrastructure capital expenditure in 2019 amounted to €306 million, a significant increase of 20 percent.

The development of the **FMD** continues to progress, with capital expenditure of €84 million matched by the same amount of project revenue. The BMBF has allocated a total

of €350 million in funding for the FMD, with Fraunhofer receiving €280 million and the two Leibniz Institutes €70 million. Through its microelectronics research, the FMD's goal is to strengthen one of Germany's key industries and help these companies modernize their technical infrastructure.

Capital expenditure on **building projects and the equipping of new facilities** rose substantially by 34 percent compared with the previous year. The amount spent on building projects increased by €55 million to €187 million, of which €155 million related to major and €32 million to minor building projects. At €35 million, spending on equipment for new facilities was on a level with the previous year. Special funding for major building projects (and related equipment) is provided by the federal and state governments in a ratio of 50:50. The state governments often provide additional funding from the

European Regional Development Fund (ERDF), which reduces the funding required from federal and state governments by an equivalent amount. Minor building projects are financed from base funding in a ratio of 90:10. The funding required from the federal and state governments in 2019 totaled €178 million. ERDF funds from the states accounted for €39 million of project revenue, while €5 million was accounted for by other revenue.

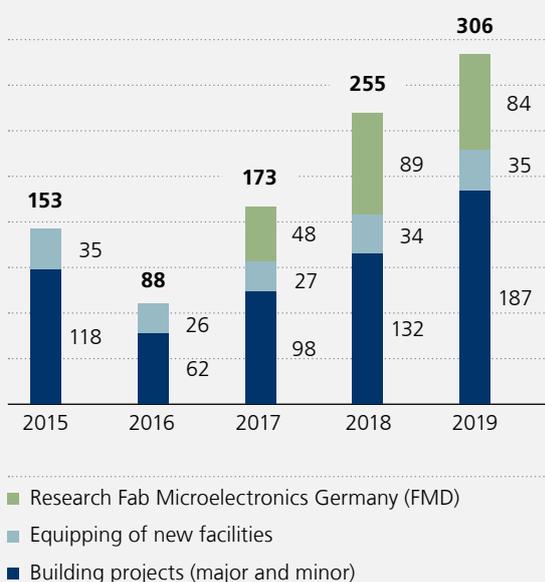
Financial and net asset position

At December 31, 2019, the Fraunhofer-Gesellschaft had total assets of €3708 million, up €263 million or 8 percent year over year. Assets presented in the ordinary accounts comprised 99.6 percent of total assets, with capital of the non-profit organization accounting for the remaining 0.4 percent.

Non-current assets accounted for 63 percent of assets and were €183 million higher at €2319 million. This increase was chiefly attributable to capital expenditure on property, plant and equipment, which exceeded depreciation of those assets. Property, plant and equipment grew by €190 million to €2250 million.

Current assets accounted for 35 percent of assets and were €91 million higher at €1309 million. The increase is principally due to a higher amount of unappropriated grants from the federal and state governments (base funding) and receivables in connection with project billing (including contracts). By contrast, cash and cash equivalents (including bank account balances) decreased by €71 million to €91 million. Of that amount, €50 million was carried forward under the terms of the management statutes. The securities portfolio increased by €31 million and, at €415 million, nearly corresponds to the license-fee revenue reserve.

Major infrastructure capital expenditure in € million



Equity – which comprises the non-profit organization’s capital that is not financed by government grants (€15 million) and restricted reserves (€16,000) – decreased 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 €185 million higher at €2306 million. The special license-fee revenue reserve grew by €31 million to €416 million. The special reserve for the present value of deferred income from a patent deal came in at €64 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 (unchanged) at the reporting date.

Provisions increased by €23 million to €197 million, €42 million of which was accounted for by provisions with maturities of more than one year. In the case of pension and compensated leave provisions, a corresponding amount of receivables from federal and state governments totaling €81 million was entered on the assets side of the balance sheet.

Liabilities rose by €26 million to €441 million. This increase is attributable mainly to an increase of €29 million in other liabilities to €36 million, of which €22 million relates to taxes. 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** operating in a diverse range of sectors. The transfer of technology to industry formed the focus of activities at 64 of the companies in the investment portfolio, while a further 20 equity investments were of a strategic nature. Equity investments also include six related companies. There was considerable activity in Fraunhofer’s investment portfolio in 2019. Overall, the organization spent some €3.1 million to acquire equity interests. The Fraunhofer-Gesellschaft added nine companies to its investment portfolio and divested its shares in nine others. The total carrying amount of equity investments (including shares in related companies) decreased to €8.6 million (2018: €9.3 million). Income from the divestiture of equity investments came to €1.1 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 2019, Fraunhofer Venture provided support to 69 new spin-off projects; in total, 26 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 innovation hub AHEAD offers a comprehensive package of targeted measures and programs to help achieve this.

International activities

The Fraunhofer-Gesellschaft's internationalization strategy is based on the principle of creating scientific value for Fraunhofer and generating positive effects both for Germany, 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**, as part of the international Fraunhofer network, represent the most institutionalized form of such collaborations:

- 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.

These legally independent Fraunhofer affiliates are constituted under the laws of their country of domicile and operate the currently 15 Fraunhofer research centers outside Germany. The latter are closely linked with local universities as their institutionalized partners, enabling long-term research activities abroad. As their work is not profit-oriented, these legally independent Fraunhofer affiliates generally qualify for base funding from their country of domicile, and they are financed in line with the Fraunhofer funding model. As part of Fraunhofer's internationalization strategy, these legally independent Fraunhofer affiliates are tasked with promoting two-way scientific collaboration between the research centers

they operate in their respective countries and the Fraunhofer Institutes based in Germany. Besides project volume generated by the Fraunhofer-Gesellschaft with customers outside Germany, the legally independent international Fraunhofer affiliates generated third-party revenues amounting to €28 million, according to their preliminary figures for 2019. Of this amount, Fraunhofer USA, Inc. alone accounted for €12 million, followed by the Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik (in Sweden) and Fraunhofer Austria Research GmbH, each with €4 million.

The **Fraunhofer Innovation Platforms (FIPs)** – formerly called Fraunhofer Project Centers (FPCs) – are vehicles enabling Fraunhofer Institutes to collaborate with research organizations outside Germany on a specific topic for a limited period of time. In each case, the partner organization sets up the FIP under its own legal sovereignty and cooperates closely with a Fraunhofer Institute in Germany on the chosen topic. This form of collaboration aims at joint research, joint projects for customers, and participation in publicly funded projects. In 2019, two new FIPs were launched in Shanghai.

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 2019, the ICON program was instrumental in initiating three new partnerships with leading centers of excellence in Switzerland, the Netherlands, and Austria.

The **Fraunhofer International Mobility Program (FIM)** was created to encourage international mobility and networking among Fraunhofer employees, and to support knowledge transfer. The novel aspect of this program is that it addresses all categories of employees (researchers, administrative staff and lab technicians) at all stages of their career. The program was successfully piloted in 2019, enabling Fraunhofer employees from Germany to spend time abroad at locations throughout the international Fraunhofer network.

Intellectual property activities

The Fraunhofer-Gesellschaft 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 research laboratories. 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) also place Fraunhofer among the most active patent applicants. In 2019, employees of the Fraunhofer-Gesellschaft submitted 733 invention disclosure reports. They filed 623 patent applications claiming rights of priority with the relevant patent offices, which corresponds to a rate of more than two patents filed per working day. Fraunhofer's portfolio of active patent families, each of which comprises all active rights in different countries, rose to 7050.

Patent applications claiming rights of priority



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 **commercial exploitation 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 2019, Fraunhofer concluded 444 new IP exploitation agreements, bringing the total number of active agreements at the end of the year to 2654. Due to the expiry of a number of licensed patents, license-fee revenue was slightly lower in 2019 than in the previous year, but still remained high at €107 million.

SELECTED ASPECTS OF CORPORATE RESPONSIBILITY

Responsibilities of the Fraunhofer-Gesellschaft

This section forms part of our non-financial report and provides a condensed overview of selected aspects of the Fraunhofer-Gesellschaft's policy with regard to corporate responsibility.

Fraunhofer sees corporate responsibility (CR) as an **all-encompassing term** that covers the economic, ecological and social aspects of its activities. The organization applies the principle of responsibility in its dealings with customers and partners, its employees, subcontractors and suppliers. Commitment to this principle is also expressed in the orientation of its research toward generating benefits for society and promoting Germany's and Europe's industrial strength. As the world's leading applied research organization, the Fraunhofer-Gesellschaft delivers sustainable solutions to meet society's future needs.

The research community's role in sustainable development includes creating a world in which ecology, economic considerations, and social equilibrium go hand in hand. These aims are anchored in the **Fraunhofer Guiding Principles**. Everyone who works for Fraunhofer is aware of this responsibility. It is not simply a question of technological innovation. The big issues facing modern-day society call for solutions that pay equal attention to environmental, economic and social factors and this equivocacy is reflected in Fraunhofer's systematic approach.

Fraunhofer responds to the **complexity** of these issues with a number of strategic initiatives towards developing systemic solutions by means of interdisciplinary research collaboration. Fraunhofer plays a significant role in the German knowledge transfer ecosystem, hence its focus on delivering solutions not only to today's problems but also to those that will be faced

by future generations. This necessarily involves abiding by strict ethical principles and answering fundamental questions, such as: What impact does technological progress have on social change? How can the emerging structural changes be steered toward the creation of a sustainable economy that gives people a sense of worth and meaning? To what extent will artificial intelligence and automation change the way in which humans interact with machines? And how can digitalization help to create a new world of work in which everyone has the same opportunities?

The motto of this year's annual report – "Our future motivation – ethics and responsibility in applied research" – echoes the importance Fraunhofer places on ethical and responsible behavior. This is anchored in the organization's structure, working methods and mission statement. The many and diverse examples of Fraunhofer research reviewed in the annual report, and the presentation of the prizewinning elevator pitches on the subject of sustainable value creation, amply illustrate this. Sustainability is also the theme of the 01/2020 issue of the Fraunhofer magazine. Its content focuses on R&D projects that deal with the question of new concepts for the use of plastics. They range from the design of new materials and closed material cycles to new recycling processes. The Fraunhofer-Gesellschaft publishes regular sustainability reports, detailing its goals, measures in place, and information on each area of corporate responsibility. The most recent corporate responsibility progress report, for 2018, was published in early 2019. This report is supplemented by an annual statement concerning compliance with the German Sustainability Code (GSC). Having submitted a Communication on Engagement (CoE), Fraunhofer has furthermore confirmed its commitment to supporting and implementing the ten principles of the UN Global Compact by renewing its membership to this international network in January 2019.

Extraordinary research projects and activities

The principles of sustainable development are also promoted at Fraunhofer by means of in-house activities and extraordinary research projects. The three following Fraunhofer projects are prime examples.

The **LamA project – charging points at the workplace** – is one of the key climate protection research projects at Fraunhofer. Funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), the purpose of this research project is to establish a charging infrastructure for electric vehicles. It forms part of the 2017–2022 Immediate Action Program for Clean Air, which addresses districts with high levels of NOx pollution. The objectives of the LamA project include promoting sustainable mobility, developing a smart energy management system for electromobility, analyzing rebound effects, and facilitating transfer of research to business and society, for example by means of acceptance and effectiveness studies. The first charging points were installed in November 2019. Ultimately there will be nearly 500 of them at a total of 38 Fraunhofer Institutes. A more detailed description can be found in the section “Projects and results 2019.”

Another internal project conducted in 2019 was a white spot analysis focusing on **global sustainability as a driver of innovation**. With reference to the UN’s Sustainable Development Goals (SDGs), this project examined Fraunhofer’s internal structures and programs to determine those with most relevance to these goals, and additionally identified the countries and areas of technology most likely to benefit from sustainable innovations. Significant R&D potential was identified in areas such as the closed-loop economy and improved transparency of global supply chains. White spots were also identified in projects designed to combat climate change and in technologies being developed to enable third-world countries to meet SDGs such as “zero hunger.”

In 2019, the Fraunhofer-Gesellschaft also set up its own **citizen science network**. The 13 participating Fraunhofer Institutes came together to discuss their experience of citizen science projects on which they had worked in the past few years, in different contexts and with different themes. The advantage of such projects is that they provide an opportunity to formulate the requirements to be met by innovative products and services from the end user’s point of view. This in turn makes it possible for researchers to adapt solutions to pressing social issues. On the other hand, citizen science raises the challenge of communicating with many more stakeholders than usual, and coordinating input from many more project participants. To answer these and other questions, the Fraunhofer citizen science network is compiling a set of guidelines that will be published as soon as it has been completed. The network’s next goals are to develop other resources to help with work on citizen science projects, including a platform enabling Fraunhofer researchers to share their experience.

Employees

The Fraunhofer-Gesellschaft has always been conscious of its responsibilities toward its employees, and continues to develop its image as an attractive employer. Key topics include staff training, incentives, equal opportunities, and employee health and safety.

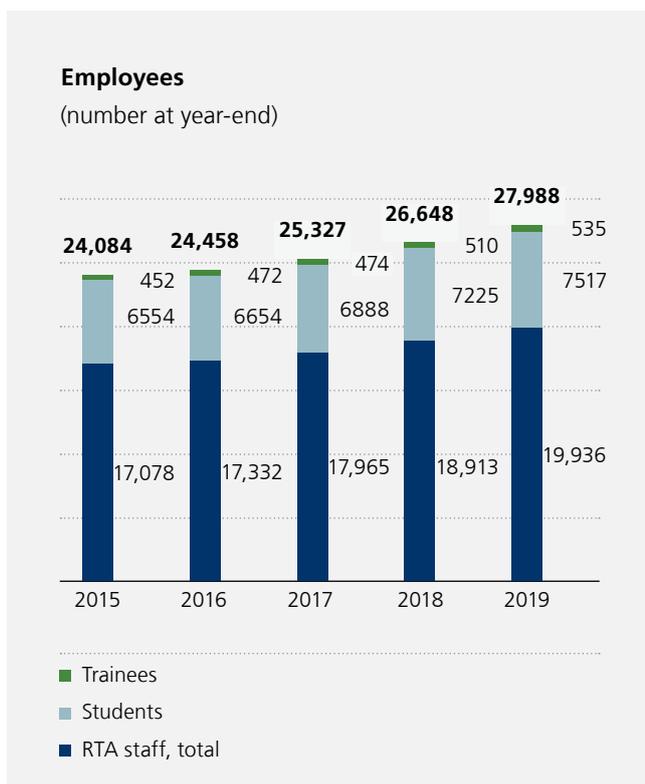
At year-end 2019, Fraunhofer had 27,988 employees, 19,936 of whom were research, technical or administrative staff (RTA staff), 7517 students, and 535 trainees. That corresponds to a year-over-year increase of 5.0 percent or 1340 employees in 2019. In absolute terms, this was a higher rate of increase than in 2018, but slightly lower in relative terms (2018: 5.2 percent).

Fraunhofer’s **human resources policy** is based on the mission-oriented approach of knowledge transfer, in which a career with Fraunhofer prepares scientists for future roles in industry or business, unless they choose to remain in research. Emphasis is given to personalized career planning. Career paths at Fraunhofer are defined in terms of skillsets, which are in turn allocated to outline training and development plans.

To assist **HR staff in the institutes** with the task of supporting employees with their career development, these staff receive specialized training and have access to a growing range of tools and other resources.

In 2019, we replaced the traditional staff reviews with more comprehensive **career development reviews**. This shifted the focus away from career paths based exclusively on academic qualifications. This move was accompanied by the introduction of a wider range of e-learning options to complement face-to-face training. Another change was that trainees and dual students are now included in the career development process. HR staff are being trained to conduct assessment interviews with this group of people, and tools and resources have been designed that are adapted to the specific circumstances of trainees and dual students.

The established **professional development programs** were continued in 2019, with targeted improvements. After a positive evaluation, the TALENTA program for female scientists and managers has been expanded to include a specifically tailored mentoring program. The Young Research Class initiative, in which junior scientists collaborate on a yearly selected range of research topics, has been placed on a longer-term footing by organizing the first alumni meeting of previous participants. The Advanced Management Class initiative, which was launched in 2018 and addresses tier-2 and tier-3 managers, was continued in 2019. Its positive evaluation has encouraged Fraunhofer to establish this program as a permanent fixture.



Skillsets	Outline training and development plans
Academic qualifications	<ul style="list-style-type: none"> ■ Doctorates ■ Funding requests and research proposals ■ Published papers ■ Speaking roles at conferences and membership of professional associations
R&D business skills	<ul style="list-style-type: none"> ■ Project acquisition and management ■ Knowledge of markets, customers and (industrial) competitors ■ Marketing, communication, presentation and negotiation
Entrepreneurial skills	<ul style="list-style-type: none"> ■ Exploitation of business ideas and creation of business models ■ Customer-centric product development ■ Marketing and sales
Management skills	<ul style="list-style-type: none"> ■ HR management ■ Leadership of research teams / thematic research areas ■ Supervision of junior scientists

Fraunhofer maintains a close relationship to the university sector, grounded not least in the practice of sharing the responsibility – between Fraunhofer and the university in question – for appointing the institute director, who in turn is awarded a university chair. In accordance with this arrangement, Fraunhofer employees also have an opportunity to undertake a doctoral project at the university. **Doctoral candidates**, who are usually employed as research fellows, profit from working in an environment that offers a blend of applied basic research, contract research and further training. At Fraunhofer, they also benefit from first-class research facilities and equipment and an open, all-round, creative working environment: in short, everything needed to successfully complete a doctoral dissertation.

To provide the best possible support to the 22 or so percent of researchers enrolled in a doctorate program at Fraunhofer each year, the guide **“Doctoral candidates at Fraunhofer – Code of Conduct”** was elaborated in 2019, in consultation

with them, the institute directors, and Fraunhofer’s Scientific and Technical Council and the organization’s general works council, for application from 2020 onward.

Percentage of research staff awarded a doctorate

Average 2016–2019	Total	Women	Men
Postdoctoral researchers	38.2	37.0	38.6
Doctoral candidates	22.4	25.3	21.6
Other students	39.4	37.7	39.8

This code of conduct includes an agreement as to the salient aspects of each dissertation project, which must be signed by the doctoral candidate, their supervisor, and the director of the institute in question.

Diversity

Diversity management improves productivity by incorporating multiple insights. Mixed teams are more creative, more innovative, and have a greater problem-solving capacity because they can take a wider view of user and application requirements in research and development. The aim of diversity management is to create a working environment in which every employee can participate on equal terms – irrespective of their ethnic origin, gender, religion, ideology, physical or other impairment, age or sexual identity.

Biases can arise either consciously or unconsciously. They tend to manifest themselves in stereotyping or prejudices. To combat this problem, the subject of **unconscious bias** is a prime focus of measures to promote equal opportunities at Fraunhofer, and is regularly featured in training and awareness events, where the response has always been positive. In the future, such ad-hoc events will be supplemented by mandatory online training for employees and managers, and appropriate workshops and training modules will be included in Fraunhofer's career development programs.

In keeping with recent legislation recognizing the rights of **non-binary persons**, Fraunhofer has revised its guidelines on the use of **gender-neutral language** to include recommendations on how to formulate communications in such a way as not to cause offense to people who do not wish to be identified as male or female.

Financial support is available to institutes planning to implement measures to promote diversity, as part of an organization-wide **diversity program**. In 2019, a total of 26 funding requests by Fraunhofer Institutes were accepted for a wide range of measures including allowing parents to bring their children into the office, diversity training, a fathers' workshop, and a gender-neutral recruitment program. For the first time, one of these accepted requests concerned the aspect of internationalization, in the form of a training course to promote employees' and managers' intercultural understanding.

The **gender-appropriate design of buildings** was another topic addressed in 2019 in the form of a checklist for the planning and execution of construction projects. It contains specific aspects that should be taken into consideration when constructing or renovating buildings. Fraunhofer is one of the first organizations in Germany to address this issue in such a multifaceted, structured approach.

Fraunhofer awards the **Fraunhofer FamilienLogo** (Fraunhofer family logo) to institutes that excel in efforts to create a better work-life balance for their employees. In 2019, the logo became established as a seal of quality, with more and more eligible Fraunhofer Institutes using it in their public campaigns to recruit talent. Moreover, the contract with pme Familienservice was renewed in 2019. As well as providing assistance with child-care, care for the elderly, and life-stage coaching, the private company offers an extensive range of information material and training courses, which is also available online.

At the reporting date, **people with disabilities** accounted for 3.0 percent of the Fraunhofer workforce (2018: 2.8 percent). As regards the issue of inclusion, the focus of activities in 2020 will be on further consolidating the diversity funding program and the guidelines for managers at Fraunhofer. Such activities will include showcasing best practices, target-group-specific communications, and raising awareness of unconscious bias.

At the behest of the president of the Fraunhofer-Gesellschaft, a **recruitment committee** has been set up to increase the number of women appointed as directors of a Fraunhofer Institute. Its aim is to hire or promote at least ten women scientists to posts as institute directors by the end of 2021, and thus increase their share in posts at this level. Fraunhofer scouts for new talent by means of three strategies. One is active sourcing, which means building up a talent pool on the basis of internal and external recommendations. The second is the use of mixed-membership talent-search committees, and the third is the use of specialized consulting agencies for the recruitment of top-level managers with experience in industrial or academic research.

As the result of a nomination round in early 2019, seven women scientists were added to the **pool of internal candidates for tenure-track appointments as associate or full professors (W2/W3 level)**. The available potential for future institute management posts is illustrated by two university appointments, several ongoing negotiations with universities, and the acceptance of five candidates for support by the TALENTA excellence program.

To increase the proportion of female researchers, and especially those in management positions, all Fraunhofer Groups have drawn up **roadmaps for this specific issue** and presented them to the Presidential Council. The roadmaps were discussed extensively in the Fraunhofer Groups and at all meetings of the Presidential Council. This shows once again how much importance is accorded to this issue within the Fraunhofer-Gesellschaft.

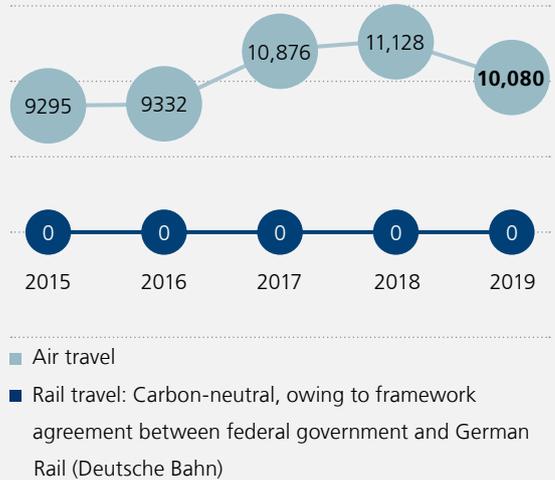
Beyond that, Fraunhofer is aspiring to increase the ratio of women on its **scientific advisory and supervisory boards**. For example, the proportion of women holding seats on institute governing boards is to be raised from 19.5 percent in 2019 to 30 percent by the end of 2020. In the Fraunhofer Senate, the organization's highest steering committee, women currently account for 38.9 percent of the elected members.

Resources – mobility and waste management

Fraunhofer researchers are often required to **travel within Germany and internationally** to attend conferences or visit customers. This can be essential for their work. Fraunhofer collects data annually on the CO₂ emissions its employees generate through business trips by train and plane. Despite the increased number of employees and research projects, air travel and hence the associated amount of carbon emissions dipped steeply in 2019 to below the level recorded in 2017. Instead, more people are traveling by train, as evidenced by the increase in total passenger-kilometers by 3.6 million to 35.8 million in 2019. This result partly derives from a resolution taken by the organization in April 2019 to reduce its CO₂ emissions caused by air travel. The ultimate goal is to replace air travel wherever possible by rail travel. Thanks to the framework agreement between the federal government and German Rail (Deutsche Bahn), all rail travel is carbon neutral.

The Fraunhofer Institutes have appointed site officers to handle **waste management** at the individual locations and to document their activities in a waste register and corresponding yearly report. Actual totals are available only for 2018. In 2018, the Fraunhofer Institutes generated 5632 metric tons of non-hazardous waste and 818 metric tons of hazardous waste. This is 70 metric tons less than the amount of non-hazardous waste generated in 2017, but 200 metric tons more in the case of hazardous waste. This difference is explainable by the fact that some projects generate more hazardous waste than others, and the amount is not always predictable. And more especially by the fact that certain institutes are called upon to work on projects that specifically deal with the processing of hazardous waste. This means that the materials they work with are classified as hazardous waste, even though they were not produced as a result of research activities.

CO₂ emissions from business travel by Fraunhofer employees, in metric tons



Volume of waste produced by Fraunhofer Institutes, in metric tons



RISK SITUATION AND OUTLOOK

Risk management and identified risks

There have been no fundamental changes in the risk situation compared with the previous year's assessment – other than the consequences of the Covid-19 pulmonary disease caused by the SARS-CoV-2 virus. None of the newly or previously identified individual risks were deemed critical at the time the **risk report** was compiled (January 2020).

The possibility cannot be excluded that the Covid-19 pandemic and measures to contain or combat the SARS-CoV-2 coronavirus may have a direct or indirect impact of certain types of risk, such as delayed delivery of purchased services, a decline in industrial revenue, capital market risks, and personnel risks. However, the full extent of the impact cannot be estimated at present. Fraunhofer is continuing to monitor the current situation with regard to the pandemic, adapting the measures already put in place as the situation evolves in order to protect the organization and its employees as best as it can.

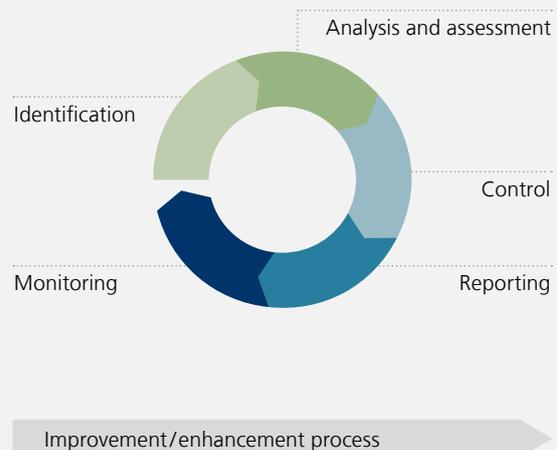
Fraunhofer understands **risk** to mean all internal and external events and developments that might jeopardize the organization's success. These include both risks that can be given a monetary value and those of a qualitative nature.

Fraunhofer's **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. To achieve this objective, a risk management system has been set up that fits the requirements and structure of the Fraunhofer-Gesellschaft, is continuously improved, and which the Fraunhofer-Gesellschaft's auditors have accepted as being adequate and suitable for the purpose.

Risk management is a cyclic process in which risk assessment experts in the operating units carry out a yearly, systematic and standardized review. The identified individual risks and proposed measures to counteract them are then summarized and prioritized in an annual risk report presented to the Executive Board, enabling individual risks of a similar nature to be evaluated collectively.

Additionally, 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.

Cyclic risk management process



Fraunhofer classifies risks according to an organization-specific model which forms the basis for the annual risk assessment which in turn serves as input for the risk report presented to the Executive Board. The first layer of the model considers four main areas of risk: business model, financing, resources and business operations. The second layer of the model assigns individual risks of specific relevance to Fraunhofer (currently 19) to these four main areas.

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 business or funding model is applied.

Financial risks may arise for the Fraunhofer-Gesellschaft from contingent liabilities and operational risks in connection with the **legally independent international Fraunhofer affiliates**. One such legally independent affiliate, Fraunhofer USA, Inc., is currently engaged in legal action with a company in the United States for the alleged infringement of intellectual property rights.

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 by the federal and state governments is one of the Fraunhofer-Gesellschaft's three main sources of financial input. It is used principally as a means of driving qualitative growth through the establishment of new fields of research. In order to maintain the share of base funding in the funding mix in the long term, Fraunhofer proactively manages its growth and lobbies the funding agencies to maintain its base funding at a level in keeping with its mission and in proportion to its performance, along with a business strategy appropriate to the research sector. 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.

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.

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

How Fraunhofer classifies risks

Main areas	Specific risk types
Business model	<ul style="list-style-type: none"> ■ State aid rules ■ Non-profit status, taxation ■ IP exploitation, spin-offs ■ Corporate strategy, portfolio management ■ International activities
Financing	<ul style="list-style-type: none"> ■ Base funding ■ Public-sector revenue ■ Industrial revenue ■ Operating expenses/Capital expenditure/Construction ■ Liquidity, pre-financing, other financial risks
Resources	<ul style="list-style-type: none"> ■ Human resources ■ IP, know-how ■ Infrastructure ■ Financial assets, reserves ■ Reputation, brand
Business operations	<ul style="list-style-type: none"> ■ Delivery of service, contractual risks ■ Legal risks ■ Information security ■ Governance, internal controlling

The ability to protect **intellectual property (IP)** by means of laws, directives and other enforceable rules plays a crucial role in Fraunhofer's success and is the prerequisite for the commercialization of research findings. Possible changes in the IP policies of standards developing organizations (SDOs) may also affect the patents underlying their standards. Fraunhofer therefore monitors initiatives stemming from the regulatory environment and assesses them for possible negative impact on the conditions governing the protection and exploitation of IP rights.

Fraunhofer is exposed to **capital market risk** insofar as it invests part of its capital and reserves with a view to earning a return. The Fraunhofer-Gesellschaft's financial investments are managed by a special investment fund under German investment law and limited partners interests. 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. In the case of international business partners, Fraunhofer faces the additional challenge of having to deal with **jurisdictions in other countries**. It manages these risks by including suitable liability restriction clauses in its standard terms and conditions of business and in its standard contracts, by engaging specialized attorneys, and through a multi-tier approval process based on competent legal advice.

Outlook

At the time this management report was compiled, it was not possible to predict the economic impact of the public health crisis brought about by the spread of the SARS-CoV-2 virus and the associated Covid-19 respiratory disease. As a cautious estimate, Fraunhofer reckons that its total business volume in 2020 will recede to a level between €2.5 billion and €2.9 billion. The three pillars on which the Fraunhofer-Gesellschaft's financial resources are based, namely base funding, public-sector project funding, and contract research, assure the organization's financial stability even in times of economic uncertainty.

In 2020, the Fraunhofer-Gesellschaft will continue to support Germany's industrial base with R&D services in all major fields of science and technology as well as conducting applied research on issues of relevance to society as a whole. The diversity of thematic areas is growing at the same pace as technological progress, also in response to topical issues. One notable example is the recent inclusion of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in the Exscalate4CoV (E4C) consortium, in which 18 partners from seven European countries are collaborating in the search for drugs to combat the new SARS-CoV-2 coronavirus. Fraunhofer IME works at the interface between biology and information science, delivering solutions of great value to the health and wellbeing of all citizens.

Dynamic and market-oriented development of the R&D portfolio is an essential element of Fraunhofer's success. The Fraunhofer Group for Innovation Research – INNOVATION carried out a **foresight process** with the dual purpose of systematically discussing new technologies and identifying social trends and how they interrelate with developments in the spheres of technology and business. The outcome of this process was a list of 51 rapidly evolving areas of interest to applied research, which will serve as the basis for further discussions in 2020 as to their possible inclusion in the Fraunhofer portfolio.

Fraunhofer's internal **Corporate Responsibility (CR) Board** selected three of these thematic areas for implementation in 2020 and assigned this task to the appropriate internal departments. They are: reducing the level of CO₂ emissions generated by the Fraunhofer-Gesellschaft, translating the reflection criteria for responsible research and innovation into operational imperatives, and providing funding for R&D projects based on ideas with as-yet undetermined market prospects.

Fraunhofer's voluntary commitment to the Joint Initiative for Research and Innovation for the period from 2021 to 2025 includes the goal of adding some 700 **small and medium-sized enterprises (SMEs)** to its customer base each year. To do so will involve expanding the existing network of High-Performance Centers and opening up other lead markets by means of concerted action and initiatives such as widening the scope of the Fraunhofer Alliances.

Fraunhofer has also set itself the goal of enabling ordinary citizens to take part in its research. In 2020, with the support of experienced Fraunhofer researchers, the organization intends to set up its own **citizen science network** to develop solutions that better meet the needs of the end users and promote the wider acceptance of research projects in which the general public is invited to participate.

With its dynamic research portfolio and stable funding model, Fraunhofer is exceptionally well placed to tackle today's technological and social challenges and, going forward, will continue to position itself as an innovation partner and provider of impulses for industry, the public sector and society.

The Executive Board would like to thank the organization's members, patrons, friends and, most of all, the staff of the Fraunhofer-Gesellschaft for their support, dedication and hard work in 2019.

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

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

REPORT OF THE SENATE ON THE FINANCIAL YEAR 2019

The Fraunhofer-Gesellschaft continued its successful performance in 2019. The creation of new research units and new research structures has further strengthened its role as a driving force and engine of innovation in the race to conquer the big technical challenges of now and the future. To this end, Fraunhofer has expanded research capacity in the key areas of energy technology, resource conservation and digitalization. The total volume of business increased by a further 10 percent in response to the growing demand for innovative research that seeks to combine commercial success with the pursuit of sustainability.

The Fraunhofer-Gesellschaft returned a solid balance sheet for 2019. Once again, the financial statements received an unqualified audit certificate from the independent auditors.

In 2019, 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 8, at the Nemetschek building in Munich; and on October 23, at the Fraunhofer Forum in Berlin.



The main decisions taken in accordance with the statute concerned the structure of the Fraunhofer-Gesellschaft and the composition of its Executive Board:

- The Senate unanimously approved – subject initially to the release of funds by the parliamentary budget committee of the German Bundestag – the establishment of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, as of December 1, 2019, and the incorporation of the International Geothermal Centre Bochum (GZB) – by way of singular succession to the Fraunhofer-Gesellschaft – as part of Fraunhofer IEG, as of January 1, 2020.
- The Senate unanimously approved the conveyance of the Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS, with its locations in Alzenau (Bavaria) and Hanau (Hesse), into the independent Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, as of January 1, 2020. The Senate unanimously approved the appointment of Prof. Dr. Anke Weidenkaff as director of this newly established Fraunhofer Research Institution.
- The Senate also approved the establishment of the Research Fab Battery Cells (FFB) in Münster, as of January 1, 2020. This new facility forms a branch of the Fraunhofer Institute for Production Technology IPT in Aachen.

- The Senate followed the recommendation of the Senate committee for the election and reelection of Executive Board members in electing Prof. Dr. Ralf Boris Wehrspohn to the position of Executive Vice President, Technology Marketing and Business Models, for the period from October 1, 2019 to September 30, 2024.
- The Senate elected Prof. Dr. Birgit Spanner-Ulmer and Oliver Zipse to the position of deputy chairs of the Senate for a three-year period of office, as of January 1, 2020.

In addition, I would like to express thanks for my reelection – as of May 8, 2019 – for what is now my third period of office as Senate chairman and for the trust you have thereby placed in me.

On behalf of the Senate, I would like to warmly thank the Executive Board and all employees of the Fraunhofer-Gesellschaft for their dedication and successful work in the financial year 2019.

Prof. Dr.-Ing.

Heinz Jörg Fuhrmann

Chairman of the Senate of the Fraunhofer-Gesellschaft

INSIDE THE FRAUNHOFER SENATE

DR. OLIVER BLUME

Oliver Blume has served as chairman of the executive board of Porsche AG since 2015. He was also made a member of the board of management of Volkswagen AG in 2018, with responsibility for group production and the sport and luxury brand group. Sport and luxury are two features that have been expertly married – under Blume’s chairmanship – in the project to build the first all-electric Porsche Taycan. Launched on schedule in 2019, the new Taycan is spearheading a technology drive at the Volkswagen Group and offers a stark lesson in how German automakers are meeting the challenges of electromobility and digitalization.

Porsche knows how to combine advanced technology and business efficiency with a sustainable production philosophy. In its bid to become a zero-impact company, Porsche is now manufacturing the company’s first ever electric sports car in a carbon-neutral process at its Zuffenhausen plant. Meanwhile, the non-profit Ferry Porsche Foundation was set up in early 2019 to provide support for social, educational and cultural projects. For Blume, taking on responsibility for society and creating sustainable value are key planks of the company ethos.

The largest restructuring exercise in the company’s history includes the creation of a battery-charging infrastructure for electric vehicles. Ionity, a joint venture with BMW, Daimler, Ford and fellow Volkswagen Group member Audi, aims to install a total of 400 rapid-charging stations along major European highways by the end of 2020.

Born in Braunschweig, Oliver Blume studied mechanical engineering. He joined Audi AG on an international trainee program and went on to work in a variety of roles for the automaker in Ingolstadt, including head of body construction for the Audi A3. He was awarded a doctorate in vehicle engineering by Tongji University, Shanghai, in 2001. Before joining Porsche, he worked at both Seat and Volkswagen. Following his appointment to the executive board of Porsche AG, he was initially responsible for production and logistics: He was made chairman in 2015.

“The automotive industry is an important part of society. It’s our responsibility to act sustainably – right across the board: economically, ecologically and socially.”





SABINE HEROLD

Sabine Herold is managing partner of the high-tech industrial adhesives manufacturer DELO, which was founded in 1961. She has occupied a variety of roles on key policymaking bodies in German business. These include membership of the steering committee for the Innovation Dialog of the German government, a seat on the SME advisory board to the German Federal Ministry for Economic Affairs and Energy, and currently as member of the board of trustees of the ifo Institute. In 2019, Herold served as a member of the founding commission for the Agency for Breakthrough Innovations.

Herold comes from a family of lawyers in Fulda. At high school, she majored in math and chemistry, before going on to study chemical engineering at Friedrich-Alexander-Universität (FAU) in Erlangen. It was a qualification that opened many doors, particularly to major corporations. She knew, however, that she would be able to achieve more in a small organization and therefore opted to join DELO, which only had 30 employees in 1989. She started work as an applications engineer. In 1997, she and her husband headed a management buyout of the company. Today, the family concern has 780 employees and posts annual revenues of 156 million euros.

DELO is based in Windach, near Munich. It is a world market leader for a host of applications that rely on specialist adhesives and light-based curing technology. Adhesives from DELO are to be found in debit, credit and SIM cards, for example, and in sensors for cars and cell phones. Over the years, the company has received an impressive array of awards, including the Innovationspreis der deutschen Wirtschaft in 2014 and the n-tv Hidden Champion Award in 2016. In 2019, the company broke the world record for the heaviest weight lifted with the aid of an adhesive and was also named one of Germany's best employers.

Sabine Herold is a member of the presidential board of the BDI – Federation of German Industries and of the German chemical industry association Verband der Chemischen Industrie (VCI). She holds the Bavarian State Medal for Outstanding Services to German Industry and was awarded the Cross of Merit of the Federal Republic of Germany in 2009.

“At DELO, 10 percent of capital expenditure goes toward digitalization. That works out at 5500 euros for each employee every year. I’m worried that there’s not much major investment in Germany right now. Policymakers need to create a more favorable climate. The tax incentives for research in 2020 are a start. But that will only work if they don’t involve too much red tape.”



DR. ROLAND BUSCH

Dr. Roland Busch has been a member of the Fraunhofer Senate since January 1, 2020. Busch was born in Erlangen and is a Siemens man to the core. His first job after joining the company in 1994 was as project leader at the central department of research and development in Erlangen. He then held posts in Regensburg and Shanghai, where he managed a variety of development projects in fuel cell technology, infotainment, automotive solutions, and local public transit and transportation systems. As an executive, he has been responsible for process, information and quality management, and for corporate strategy.

Busch holds a doctorate in physics and is chief technology officer at Siemens AG. He was also appointed deputy chief executive officer of the managing board on October 1, 2019. In this capacity, he is responsible for implementation of the Vision 2020+ strategy at Siemens. One of the key tasks currently facing the company is industrial digitalization.

Busch's responsibilities in the fields of corporate technology and corporate development cover the following company activities: the Internet of Things (IoT), strategy, operations, sustainability, portfolio companies and global business services. He is also chair of the supervisory board at Siemens Mobility GmbH and head of next47, Siemens' accelerator unit for start-ups. As of December 2019, he is also responsible for labor relations.

Busch sits on the supervisory board of a number of companies. These include OSRAM GmbH, Atos SE and the European Business School of Management Technology, in Berlin. He is a member of the board of governors at RWTH Aachen University, of the university council of Friedrich-Alexander-Universität Erlangen-Nürnberg and of the management board of Plattform Industrie 4.0, a federal government initiative.

"In the age of digitalization, research and development needs to be fast and open. But above all it requires a clear technological focus. If not, it will struggle to meet the fast-changing requirements of the digital age."

NATALIE MEKELBURGER

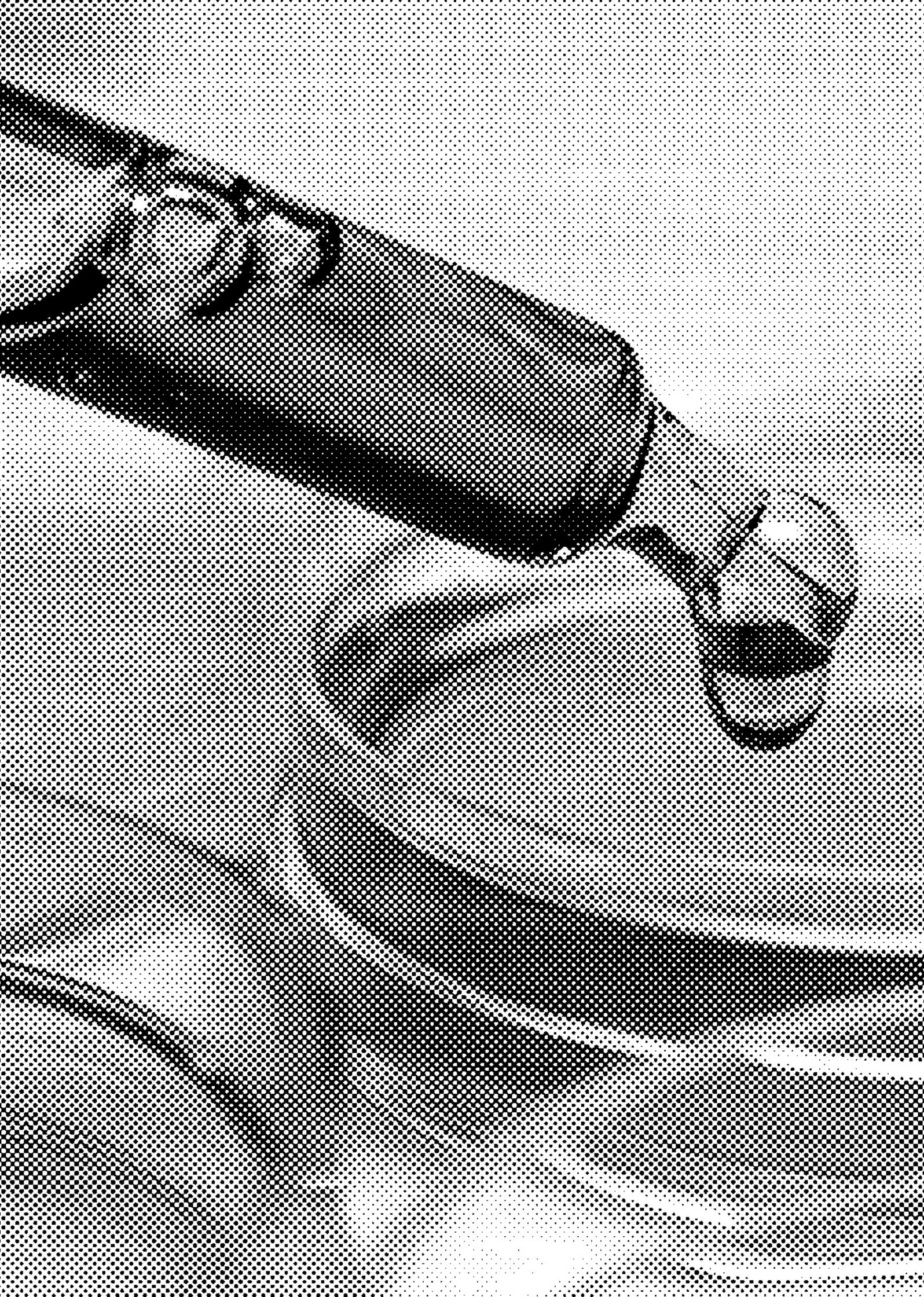
Natalie Mekelburger is president and chief executive officer of the independent, family-operated company Coroplast Fritz Müller GmbH & Co. KG. She is a member of the third family generation to run the company. In 1928, Fritz Müller, her great-uncle, founded the company, then known as Manufaktur für Elektroisoliermaterialien. Ninety years later, it has become a global player and technological leader for industrial adhesive tapes and wire harnesses, including high-voltage electrical distribution systems for electric vehicles. In the period since Mekelburger joined the family company in 1994, revenues have more than tripled, rising to 500 million euros in 2018.

Coroplast products are used in a host of sectors, including automation systems, medical engineering, machinery and plant engineering, furniture manufacture, white goods and the construction industry. One of Coroplast's largest customers is now the automotive industry. Mekelburger forecasts a challenging business climate for the company: "Trade wars and new policies in response to the climate debate are two of the big factors creating turmoil in the automotive industry. We are also seeing new market players and new types of mobility emerge."

Mekelburger regards herself as an out-and-out entrepreneur. In 2017, she was voted businesswoman of the year in the category for industry by the auditors and consultants EY. After gaining her degree in business administration, she first worked for a management consulting company, before joining Coroplast as head of marketing and sales. She has been president and chief executive officer of the company since 2006. In 2017 and 2018, Coroplast called in Porsche Consulting to help develop a new corporate structure to meet the challenges of the future. This was in response to strong growth coupled with market volatility and political and social uncertainty.

"We need to stay responsive and move with the new trends in mobility, whatever they may be. If we can do that over the next 10 to 15 years, then we will have achieved a lot. But it also means focusing on the customer and staying flexible."





REVIEW OF FRAUNHOFER RESEARCH

OUR FUTURE MOTIVATION – ETHICS AND RESPONSIBILITY
IN APPLIED RESEARCH

NEW INITIATIVES AND INFRASTRUCTURES

PROJECTS AND RESULTS 2019

AWARDS 2019

VISIONS THAT WILL SHAPE TOMORROW'S WORLD

PEOPLE IN RESEARCH

FRAUNHOFER INSTITUTE SPIN-OFFS



OUR FUTURE MOTIVATION – ETHICS AND RESPONSIBILITY IN APPLIED RESEARCH

The ethics and the conduct of institutions has become a key topic of public and political debate. In turn, Fraunhofer has found itself increasingly under the spotlight. This also stems from the remarkable transformation that the Fraunhofer-Gesellschaft has undergone since it began life on March 26, 1949.

In the early days, Fraunhofer comprised but a small number of volunteer staff, who had set themselves the goal of raising the funding required to build up a body of applied research in Germany, with a focus on innovation. While Fraunhofer has preserved its German roots, it has also become very active on the international level. Today, it has a workforce of 28,000 employees, all of whom are dedicated to developing technology that benefits business and society.

This extraordinary success story is punctuated by some major milestones in applied research. Each of them has had, in one form or another, a lasting impact on practically everyone's life, and each one remains indelibly associated with the name of Fraunhofer. A prime example is the mp3 coding system for music files, which reduces data storage requirements to less than 10 percent. It revolutionized the music industry and can now be found in literally billions of media players. Another is the white LED, which has not only transformed display systems but also created a host of new applications for the lighting industry.

These and other innovations, along with our growing stature as a research organization, have brought Fraunhofer increasing renown within the scientific community and in the political and public realms. This in turn has generated certain expectations regarding our ethical conduct and professional integrity. We are therefore obliged to ensure that our structure, our working methods and our mission conform to these standards.

Creating value and prosperity

As a non-profit research organization, our primary goal is not to pursue our own enrichment but rather to enable value creation and thereby help generate prosperity for Germany and Europe. By working to develop promising new technologies, Fraunhofer makes a substantive contribution to our project partners' commercial success and to the competitiveness of industry as a whole. Investment in applied research has a significant impact on Germany's economic power. Alongside such quantifiable microeconomic and macroeconomic effects, the Fraunhofer-Gesellschaft also has influence as a result of its strategic involvement in questions of an overarching social and political significance. This participation obliges us to maintain a properly scientific distance and to ensure that our input remains purely factual. In addition, we must remain unbiased with respect to the results of our work and ensure that our research and development activities follow a path endorsed by society. If applied research is to be more than merely relevant to the market and its needs – if it is also to contribute to society's well-being – then it requires a set of guiding principles that are based on clearly defined values.



Sustainability, environmental protection, decarbonization

As a German research organization and a key member of the European research community, the Fraunhofer-Gesellschaft acknowledges its commitment to the principles of sustainability and thereby to the United Nations' Sustainable Development Goals. Our fields of research and areas of expertise are intended to meet the current and future requirements of our customers in industry and the public sector. Our research is geared towards society's needs in the areas of health, security, communications, mobility, energy and the environment. The work we do has therefore a major impact on people's lives. As such, we enjoy the trust of government, business and the public. This is what commits us to generating knowledge, ideas and solutions that serve people's needs. Our ongoing research effort helps ensure that Germany can maintain its strong position in key areas of technology such as the materials sciences and intelligent, connected manufacturing.

By adopting a strategic position from the outset, Fraunhofer has risen to become a world leader in the technology required for a carbon-neutral economy. At Fraunhofer, we ensure a productive crossover between all of our cutting-edge research in wind power, solar cells, energy generation and storage, power grids, electromobility, and information and communications technology. This boosts our ability to react quickly to developments in domestic and international industrial policy and to shape the transition to a new energy system.

Fraunhofer is also a reliable and agile partner to the public sector and industry in areas of technologies that will first become relevant in the short to medium term and are therefore still at early stages of development. This includes hydrogen technology, which many regard as providing the key to a decarbonized economy. This because hydrogen enables sector

coupling in the energy system; delivers solutions for sustainable mobility, industrial manufacturing and the circular economy; and provides a bridge between the electricity, gas and heating grids. It is therefore an increasingly important technology for the major industrial and emerging nations. With countries around the world preparing to ramp up this market, Fraunhofer is poised to play a leading role as a key R&D partner in the development of the hydrogen economy.

Data sovereignty and data security

The Fraunhofer-Gesellschaft is playing a proactive role in the overlapping areas of data sovereignty and data security – a field of major importance to a host of sectors. Through its involvement in the International Data Spaces initiative, Fraunhofer is a key member of GAIA-X, a project of the German federal government. The primary purpose of GAIA-X is to provide safe storage of so-called data at rest, whereas IDS will create the framework for so-called data in use. These two elements form key planks of a European data sovereignty initiative, which would enable Europe to pursue its own sovereign strategy in the field of data protection, thereby marking a milestone for European business and society.

Technological change requires structural change

Digitalization and the transition to a new energy economy are two areas that illustrate the impact and penetration that certain key technologies will have in the future. Sector coupling, for example, or data-driven health care will both require more than just an evolution of current systems. Both will require a radical paradigm shift. The profound structural changes to industry brought about by digitalization will also be felt on varying scales at the local and regional level – as will the coming



transition to new systems of energy and transport. This will ask big questions of German and European industry. In response, companies will need to respond with innovative products, innovative processes and innovative business models, while also being expected to meet ambitious climate targets. For energy-intensive industries, such changes entail major risks. Yet they also present an opportunity to help realize the first example of a sustainable industrial economy.

Now set in motion, this transformation will have a major impact on traditional lifestyles and patterns of consumption. In the process, entire regions will be able to act as living laboratories and show how the milestones to climate neutrality can be achieved by encouraging industry to adapt to the future in a profitable way and also by involving the public at large. Regions affected by the phaseout of coal, in particular, now face acute challenges. These range from strengthening the local economy and creating good jobs to climate protection. Fraunhofer is on hand here to form a link between policymakers, industry and the scientific community.

At the same time, structural change can also bring new opportunities, not least when flanked by political measures that build on training and modern technology in order to make a region more attractive and innovative. This marks a shift away from a backward-looking debate and focuses instead on how we intend to live and work in the future. It also entails an investigation of the technological developments that will impact industry and policymaking in years to come. Given such changes, how best can we maintain our competitiveness and thereby our prosperity?

Foresight and future technology

To mark its 70th anniversary, Fraunhofer carried out an extensive foresight study to chart the broad spectrum of emerging trends in applied research. Unsurprisingly, the three key technologies with relevance to all business sectors were microelectronics, nanoelectronics and artificial intelligence (AI). All three should therefore be promoted as much as possible by government, research-funding bodies and the scientific community. At the same time, the corporate sector needs to revise its attitude towards innovation. If not, the declining level of innovative breakthroughs by German SMEs will compromise their strong market position. Fraunhofer's Research Fab Microelectronics Germany (FMD) provides streamlined access to next-generation technology for small and medium-sized companies. In so doing, it eases the industrial transfer of new developments such as multifunctional, energy-saving sensor technology, communications systems and power electronics. Many of our institutes are also involved in developing key technologies for AI, cognitive systems and machine learning. These projects cover a wide variety of applications tailored to our customers' concrete requirements.

The Fraunhofer foresight study also showed that new technologies such as climate engineering, human-computer interaction and the reprogramming of human cells require proper governance. Based on extensive input from stakeholders in government, business and society, this will ensure that all the legal and ethical issues receive due consideration at an early stage of development. Quantum technologies, meanwhile, look set to become a real game changer. This could well lead to groundbreaking developments in a host of fields. Possible applications range from quantum optics for the enhanced diagnosis of disease to quantum computers for solving extremely complex optimization problems in areas such as connected traffic systems, medical diagnostics and the simulation of properties of new materials.

Refocusing on systems research

These new technologies look set to penetrate society to a radical degree and unleash major transformation. In view of this, we need to revise our understanding of the role of the engineering sciences and our responsibilities in this respect. As defined in our mission statement, the Fraunhofer-Gesellschaft pursues applied research for the benefit of society and to strengthen the German and European economy. In recent years, there has been a perceptible shift in focus within this very broad mandate. Technology is and will remain the prime instrument for tackling the challenges facing society. Nonetheless, we should also favor an approach that is more clearly focused on solving specific problems and that is geared towards clearly identified social needs. Innovation only addresses part of the problem. The introduction of new technology is only truly effective when accompanied by policymaking and modifications to social behavior. This is the lesson of the ongoing transition to sustainable systems of energy and mobility, sustainable agriculture, and the circular economy.

Increasingly, Fraunhofer's role must be to initiate or promote collaboration between relevant stakeholders from industry, science, government and research funding. Fraunhofer has already proved a key partner in areas of regulation and standardization – including efforts to achieve technological sovereignty for Europe. This shift towards systems research means more than ever that Fraunhofer must build flexible networks in order to connect its expertise and capacity within its own organization and within the wider scientific community.

**Corporate governance and
the Fraunhofer Future Foundation**

In 2017, the Executive Board set up a Future Commission to collectively drive forward a process of organizational change. After two years of work, the commission submitted its recommendations at the end of 2019. The Presidential Council will decide in 2020 which structural changes are to be implemented. One thing is already clear: the primary purpose of reorganization will be to strengthen our leadership role in key technologies with a major innovation potential for German industry. The introduction of new incentives, such as the creation of virtual institutes within the Fraunhofer organization, will not only help counteract a natural silo mentality but also have a profound and positive impact on corporate governance. For example, it will require less effort to establish initiatives and consortia involving different institutes and research bodies. This in turn will expedite the process and make it more flexible – thus ensuring that full advantage is extracted from Fraunhofer's concentrated fund of expertise. In addition, we plan to make our research services more easily and quickly accessible for our customers.

At the same time, we intend to shift the focus of the non-profit Fraunhofer-Zukunftstiftung (Fraunhofer Future Foundation). In the future, funding will be geared towards a form of value creation based on ethical principles. It will also, however, continue to focus on commercial viability and on the idea that the supported projects should contribute to solving the global challenges facing society. In addition, the provision of funding on a smaller scale will help establish an attractive portfolio for future fundraising activities.



Research guidelines, ethics committee and code of conduct

As a systems research provider and organization committed to shaping the future, Fraunhofer has long encouraged a greater responsibility with regard to research freedom and the risks this entails. The more technology impinges on our world, the greater our responsibility for it – not least when that technology may have an incalculable impact on civilization. In elaborating a set of values as our guide, we too must therefore ask more closely about the goals and principles that underlie socially sound activity in the fields of technology and business. A rapid growth in knowledge has rolled back the boundaries of what is technologically feasible. As a consequence, Fraunhofer employees are increasingly confronted by ethical questions. In 2014, we therefore established a Fraunhofer-wide ethics consultancy service. This was followed in 2019 by an ethics committee, which convenes on an ad hoc basis.

Neither of these bodies is concerned with making decisions or passing judgments. Instead, their job is to evaluate and to substantiate ethical positions by means of reasoned arguments based on normative principles. As evidenced by society's changing attitudes toward the use of substances such as alcohol, or advances in reproductive medicine, moral concepts are subject to gradual modification. Furthermore, our experience with the democratization of IT shows that future abuses and misuses are not always evident at the development stage. Sometimes, the scale of the impact and the need for regulation only becomes apparent once the technology is in place. Norms of a technical-ethical nature are formulated within an existing economic order and within a complex system of causal relations between policymakers, lawmakers, regulatory authorities and society itself. Research organizations operate within this system. As part of it, they are expected, first and foremost, to assume a prospective responsibility for what might happen in the future.

The obligations of Fraunhofer researchers in terms of responsible and ethical behavior have been enshrined in the Fraunhofer Code of Conduct since 2015. Researchers are individually responsible for addressing ethical issues within their own field of research and for exploring the interrelationships between technical, social, economic and ecological systems and their likely consequences in the future.

Prospective responsibility can be exercised in a variety of ways – for example, by promoting an interdisciplinary and intercultural debate within the scientific community about the consequences of biological transformation or the blurring of boundaries between humans and machines. Similarly, by providing clear information on the current state of a technology and its development prospects, scientists can help the state fulfill its duty of care towards citizens. This already happens with regard to autonomous systems in security environments, for example, or robotics in the care industry, and big data in the health sector. When it comes to introducing new applications in the fields of medical engineering or information and communication technology, our participation in standardization processes means we play a decisive role in establishing quality standards and ensuring that such systems feature embedded ethics. Our scientists are therefore involved in various ways to help expound and update the relevant legal and political provisions in line with ethical considerations.

Owing to the progressive globalization of research, there is now an increased risk that research involving sensitive ethical issues may be conducted by Fraunhofer entities outside of the EU and in a manner that would not be ethically acceptable in Europe or Germany. Here, observance of, and compliance with, foreign trade regulations is a priority for Fraunhofer. Similarly, any research project involving the participation of Fraunhofer Institutes is governed by basic principles such as respect for human dignity, solidarity, autonomy, participation, freedom of opinion, democracy, data protection and informational

Our future motivation – ethics and responsibility in applied research

self-determination. Asia is currently a growth region for Fraunhofer, and our cooperation with Chinese partners has been the cause of some controversy in recent times. Here, too, Fraunhofer has its own digital auditing processes to ensure that our international activities do not conflict with our values and interests.

Firing enthusiasm for technological progress

By seeking to anticipate risks, we also help ensure that new technologies are not regarded as dangerous even before they enter into use. We advocate adopting an open and positive attitude towards future technologies. If people regard artificial intelligence, for example, as essentially unmanageable and share a fear that it could spin out of control, then we might end up missing out on major developments.

The establishment of our FUTURAS IN RES series of science conferences has created a platform for an interdisciplinary discussion of the opportunities and risks associated with future technologies. Fraunhofer Institutes also participate in many other congresses, symposia and debates. Our contributions are designed to address people's concerns about new technology and raise questions about what the future might hold. How, for example, will artificial intelligence impact everyday living? And how can we improve people's lives and society as a whole? Yet it will take more than a communications campaign to get industry and society fully involved. Technological progress has to be accepted throughout all layers of society. Our job is therefore to conduct intensive research on the security aspects of AI. At the same time, we aim to fire young people with enthusiasm for new technology. For only then can we ensure that they will produce new business ideas, innovative start-ups and cutting-edge research – and thereby help generate future prosperity.

Trust is founded on scientific integrity

Fraunhofer scientists work hard to maintain the trust we enjoy in government, business and society – and to cultivate the good relations we have with our customers, funding bodies and partners. This trust is rooted in the proper scientific care we exercise in experimentation and publication – including, of course, full compliance with the rules of good scientific practice. Rules and procedures for the institutes and research institutions of the Fraunhofer-Gesellschaft were enshrined some years ago in the "Fraunhofer Policy zur Umsetzung wissenschaftlicher Integrität" (Fraunhofer policy to assure scientific integrity). In 2019, the Deutsche Forschungsgemeinschaft (DFG) issued new "Guidelines for safeguarding good research practice." These focus less on infringements and prosecution, and more on promoting scientific integrity and professional ethics among scientists. Fraunhofer is to issue an organizational directive governing the mandatory adoption of the updated DFG guidelines.

Prevention of corruption

As a beneficiary of public funding, the Fraunhofer-Gesellschaft has a special responsibility to behave in an exemplary manner in its business dealings. This means not only complying with laws and statutory regulations but also negotiating on fair terms and fulfilling contractual obligations. In addition to being bound by special regulations, Fraunhofer is also subject to regular audits by the German Federal Court of Auditors, the local tax office and external auditors. Fraunhofer regulations are available for consultation throughout the organization. We also hold regular training sessions and events to raise awareness on issues such as compliance, the prevention of corruption, and data protection. Our internal audit department performs audits on specific topics.



In particular, Fraunhofer executives are responsible for ensuring the success of our organization and for contributing to a positive working environment. They have an exemplary role to play in preventing corruption, ensuring scientific integrity, dealing properly with customers, maintaining confidentiality and conserving resources in the workplace. In addition, the Fraunhofer Code of Conduct sets out the Executive Board's basic expectations regarding the conduct of every employee, regardless of their position within the organization.

New Work: Creating modern, attractive workplaces

Digitalization and wide-ranging social and economic pressures have brought major changes to the world of work across all sectors of the economy. The climate debate, for example, has plunged us into a profound discussion of values and systems. Global systems of value creation and key technological transformations have wrought major changes to the economy. At the same time, we face radical social changes.

Fraunhofer's mission is to deliver applied research and promote innovation. We represent the spirit of open scientific inquiry. In line with our statutes, our job is to make a vital contribution to the economy and the society of our country. Together with our Corporate Responsibility (CR) Board, we have been looking at key issues regarding responsible research and gender equality. At present, this includes an initiative aimed at achieving climate neutrality for the entire Fraunhofer-Gesellschaft. Our employees say that the values and objectives embodied in this work are a key source of motivation in the workplace. Being part of Fraunhofer means working in a field that can be subject to rapid change – and therefore being able to meet the challenge to adapt. But it also means having a say in how that work is done – not only its substance and focus, but also the time and the place at which that work is done, the people with whom it is done and the way in which it is organized.

At Fraunhofer, we need to ask ourselves how best to handle the most important asset in our organization – our know-how – and how to convert that into sustainable value as productively as possible. Our New Work@Fraunhofer project has investigated working practices within the Fraunhofer-Gesellschaft and defined the requisite measures as well as described the challenges ahead. Follow-up pilot projects will now implement pioneering concepts for new working practices as well as investigate their scope and limitations.

Equal opportunities and diversity

The purpose of diversity management at Fraunhofer is to create a working environment in which every employee can participate in equal measure, irrespective of ethnic origin, gender, religion, ideology, physical or other impairment, age or sexual identity. This creates a diverse culture that can bring additional benefits. For example, mixed teams tend to perform well on account of their greater creativity and ability to innovate and solve problems. By the same token, decisions made by mixed teams are, as a rule, more workable and acceptable. Finally, when a research and development team reflects different perspectives, it is easier to take account of differing needs and modes of application.

The growing international competition for outstanding researchers and top scientific talent means that Fraunhofer is now obliged to look upon all capable and motivated workers as potential employees. As a prospective employer, we must ensure that all our job offers are as attractive as possible for potential employees.

Communications

Technological innovation must be flanked by a public discussion of the accompanying opportunities and risks. This in turn requires that the underlying research be explained in an intelligible way and its benefits to society made clear. It is only by recognizing and understanding the structural changes brought about by new technology that we can then actively influence its impact on the economic, social, political and cultural level. Recent years have seen a burgeoning discussion about the work done in the scientific community. In turn, science communication has become a well-established discipline within German science. Indeed, it has been made part of the German federal government's Pact for Research and Innovation and is now a prerequisite for many research-funding decisions.

For a research organization that seeks to have a positive impact on people's lives, it is vital that we maintain an open dialog with the general public. All innovation implies change. In a democracy, however, this can only be achieved with society's consent. One of our tasks is therefore to communicate the results of our research to the general public in an intelligible way and to highlight the benefits of the scientific work we do. Only in this way will people be able to judge the scientific work we do and the results we achieve. And only then will interested parties be able to influence the process of structural change brought about by new technology. Communication in all its forms has therefore a decisive and indispensable role to play in the implementation and effectiveness of research and development.

The Fraunhofer-Gesellschaft employs communications to present new research findings, situate technological developments within a broader context and inform the general public about new scientific trends. We strive to explain complex scientific topics clearly and comprehensibly and in terms of their potential applications. Our job is to provide information and clarification, and to help generate acceptance for, and reduce anxiety about, new technology. By responding quickly and flexibly to inquiries from the public and the media, and by providing diverse publications and platforms for dialog, we are able to meet our obligations in this vital sphere while also reflecting current digital trends in communication. For example, the impact of digitalization and artificial intelligence on society has been subject to critical debate. As a research organization with experience in the domains of science and business, it is our duty to promote an objective discussion based on a balanced presentation of the facts, including the necessity for such technology and the opportunities it brings.

Policymaking on the German and the European level is of vital importance here. This is where decisions are made that will determine the future direction of research and how it is funded. Given its focus on applied research with a direct impact on the economy, society and the environment, the Fraunhofer-Gesellschaft has an important advisory role to play – one that it exercises with proper care. For example, we seek to initiate discussions with relevant experts and decision-makers.



As political and social debate becomes increasingly polarized, there is less and less scope for discussions that are aimed at achieving consensus. At such times, politically neutral organizations like Fraunhofer have a natural role to play: to contribute, as best we can, to promoting an objective dialog and creating a constructive climate of debate. It is our responsibility not only to lead a productive discussion but also to contribute, as effectively as we can, to ensuring the well-being and prosperity of Germany and of Europe. We do this in the knowledge that, by and large, it is prosperous societies that have the opportunity and the endurance required to guide sociopolitical debate to a meaningful consensus without fear for their own economic well-being. In such questions, we remain, as ever, rigorously committed to party-political neutrality. And, as always, our objectives are wholly geared toward people's well-being and that of society as a whole.

Given our mission to have a direct and positive impact on science, industry, working methods and lifestyles, the Fraunhofer-Gesellschaft has a special role to play in Germany and Europe. As the world's leading organization for applied research, we fully acknowledge the responsibility that this entails.

Prof. Dr.-Ing. Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

NEW INITIATIVES AND INFRASTRUCTURES

The Fraunhofer 2022 Agenda was launched in 2017. It provides Fraunhofer with a road map that guides it toward future goals. Along this route, our priorities are to deliver sustainable scientific excellence – right from precompetitive research to industrial transfer – and to exploit synergies so as to secure research contracts in systemically important fields. Further key objectives of the Fraunhofer 2022 Agenda are to attain scientific leadership in vital areas of research and to spearhead the response to the challenges facing society. Among these challenges are climate protection and the transition to sustainable energy and mobility systems, the development of a hydrogen industry, the establishment of a circular economy, and the digitalization of industry. Last but not least, Fraunhofer will also focus on maintaining the competitiveness of the German and European economies.

In the years 2018 and 2019, the Fraunhofer 2022 Agenda team instituted a Future Commission, the purpose of which was to review the components of the Fraunhofer portfolio. As of 2020, the results of this process are now being implemented. For example, we are reorganizing our Key Strategic Initiatives (KSIs) into an even more effective format. At the same time, we are restructuring our range of services so as to underscore our achievements in transferring new technology to industry. Finally, we are reorganizing and reconstituting the Fraunhofer Groups so as to preserve and strengthen their scientific eminence in their respective areas of expertise.

Ad hoc initiatives

Research Fab Battery Cells (FFB)

Fraunhofer opened a new research facility for battery cell production in Münster in October 2019. It forms part of the Battery Research Factory umbrella program of the German Federal Ministry of Education and Research (BMBF) and is scheduled to receive a total of 700 million euros in funding over the coming years. The new facility reflects Germany's growing importance as a location for battery technology and production. In addition to stepping up the already outstanding research being conducted in Germany into the mass production of battery cells, FFB will also reinforce the supply industry by providing, for example, new materials for battery cells, production technology for more-efficient batteries, and measurement systems for quality assurance. This new facility, a branch of the Fraunhofer Institute for Production Technology IPT, will work with partners and customers to develop new battery concepts and corresponding production processes. This will boost innovation and commercialization, thereby reducing the risks involved in transferring new design concepts and production systems to mass production. FFB is collaborating closely with the University of Münster, RWTH Aachen University and with various other partners and customers.



Next-generation computing

New and increasingly powerful processors and systems are required for the further digitalization of society and industry. Technologies such as cloud computing, artificial intelligence and machine learning all generate and process huge amounts of data – so-called big data. The same is true of highly complex applications such as Industrie 4.0 and autonomous vehicles. Here, standard computers are too weak and too slow – and consume too much energy – to handle the volume of data produced by these new technologies. At the same time, we need ways of ensuring data sovereignty for applications in cloud computing, big data and 5G connectivity. This ranges from standardization work – spearheaded, for example, by the “Trustworthy electronics – made in Germany” initiative – to the development of a European system-on-chip security architecture and a European production chain for semiconductor manufacturing.

Next-generation computing aims to develop methods of processing huge volumes of data quickly, securely and efficiently in terms of energy consumption. Fraunhofer’s contribution, which is being spearheaded by the Fraunhofer Group for Microelectronics and the Fraunhofer ICT Group, is to link trusted computing with neuromorphic and quantum computer systems. This work is expected to spawn new developments across a host of sectors that form the backbone of European industry, including communications technology, production and automation systems, automotive technology, robotics, health care, commerce, banking and insurance. The Research Fab Microelectronics Germany (FMD) is providing the technology base and a joint research platform for this work. The creation of a new Fraunhofer Cluster of Excellence will lead to the establishment of a national infrastructure of living labs. Initial projects to foster strategic cooperation with European research partners CEA-LETI and IMEC were launched in 2019.

Smart Ocean research initiative

The ability to exploit the seas is of vital importance to Germany and Europe – as is the need to respect and protect the marine ecosystem. The race to develop new technology is accelerating all the time. On the basis of such developments, novel techniques for tapping this potential are now being rolled out worldwide. Once again, the emphasis must be on respecting the ecological significance of the world’s oceans. As the place where land and sea meet, coastal regions are a key locus for investigating the interaction between these two economic spheres. In consultation with the state of Mecklenburg-West Pomerania and the city state of Hamburg, Fraunhofer is now expanding its research activities at locations in Rostock and Hamburg. Here, our Smart Ocean program will strategically reinforce Germany’s capabilities in the field of maritime technology.

We are also expanding research at the Fraunhofer Center for Maritime Logistics and Services CML at our location in Hamburg. These activities will focus on innovations for port systems, shipping, shipbuilding and maritime logistics. Their purpose is to deliver new technology and know-how that will strengthen the maritime economy as a whole. Research will be conducted in the following areas: green shipping, zero-emissions cargo handling, innovative vessel design for shipbuilding, and seamless logistics in port. Many of the key technologies required to achieve systematic improvements in the maritime economy rely on digitalization. Fraunhofer is therefore seeking to combine existing knowledge of maritime processes at the Port of Hamburg with the two new technologies of digitalization and artificial intelligence – and thereby develop smart and secure processes with real-time capability. The infrastructure for this will be conveniently located right next to the Port of Hamburg, Germany’s largest seaport.



1

The Ocean Technology Campus is currently under development at the Fraunhofer location in Rostock. It will comprise a new institute building, located in Rostock's fishing port, and the Digital Ocean Lab, an undersea test site built on an artificial reef off the coast of Nienhagen. Under the leadership of the Fraunhofer Institute for Computer Graphics Research IGD, this new facility will investigate and develop marine systems and deep-sea technology in the waters of the Baltic. This lighthouse project involves the participation of the City of Rostock, Rostock Business, the state government of Mecklenburg-West Pomerania and partners from industry. The Fraunhofer-Gesellschaft has put together a research group comprising the Fraunhofer Institutes for Computer Graphics Research IGD, for Large Structures in Production Engineering IGP, for Optronics, System Technologies and Image Exploitation IOSB and for Ceramic Technologies and Systems IKTS. This will develop and trial marine-capable systems and technology for applications including cable tracking, maintenance of offshore structures, and the detection and disposal of abandoned munitions.

New institutes and research institutions

Fraunhofer Institute for Large Structures in Production Engineering IGP

The creation of this new institute, based in Rostock, is the culmination of 20 years of successful research by its predecessors. Founded in 2000 as a Fraunhofer Application Center, it became an independent Fraunhofer Research Institution in 2017. With its interdisciplinary approach to production engineering, it has over the years been able to build up a broad customer base in sectors such as shipbuilding, the maritime industry, steel construction, aircraft construction, wind power systems, energy and environmental technology, and rail and commercial vehicle manufacturing – all areas in which special demands are made of materials. It became a fully fledged Fraunhofer Institute in 2020. Fraunhofer IGP celebrated the acquisition of this new status in May 2020 – at a topping out ceremony for a new institute building.

This new institute building will accommodate further research in the field of Werft 4.0 – the digitalized shipyard. Fraunhofer IGP is the only Fraunhofer Institute in Mecklenburg-West Pomerania and specializes in the fields of production engineering, production processes and underwater materials. As one of the institutes participating in the Ocean Technology Campus, it is currently working on OWSplus – Floating Offshore Wind Solutions, a regional growth core funded by the German Federal Ministry of Education and Research (BMBF). Here, project partners are developing solutions for the next evolution in renewable power generation.



2

Fraunhofer Institute for Cognitive Systems IKS 2

The newly founded Fraunhofer Institute for Cognitive Systems IKS incorporates the former Fraunhofer Institute for Embedded Systems and Communication Technologies ESK. It forms part of the Artificial/Machine Intelligence network of the state of Bavaria and works to develop safe and reliable cognitive systems, devices and machines. In adding artificial intelligence to Germany's rich engineering tradition, it aims to deliver a product that combines intelligence and quality. AI in secure systems must be both intelligible and robust. To achieve this, researchers draw on their expertise in designing and constructing flexible architectures that are highly connected and extremely reliable. Conventional systems are used to monitor AI's susceptibility to error. For cost reasons, such systems have to remain dynamic. Risk analysis is therefore used to decide in any one situation how security methods should be modified.

As a key member of the Artificial/Machine Intelligence network of the state of Bavaria, Fraunhofer IKS maintains close links to the Technical University of Munich and to Ludwig-Maximilians-Universität München. In line with its AI strategy, the Bavarian state government plans to construct a new building for Fraunhofer IKS on the research campus in Garching, near Munich. In parallel, the Fraunhofer Institute for Applied and Integrated Security AISEC is to expand research activities in the field of cognitive security, and the Fraunhofer Institute for Integrated Circuits IIS in the field of AI for digital signal processing. Finally, blockchain research conducted by project groups at the Fraunhofer Institute for Applied Information Technology FIT in Augsburg and Bayreuth is to be expanded, and the Fraunhofer Institute for Transportation and Infrastructure Systems IVI is to coordinate the establishment of an Application Center for Connected Mobility and Infrastructure in Ingolstadt.

Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG 1

In early 2019, the federal government commission on growth, structural change and employment agreed to a phaseout of coal-fired power generation. In the future, the German energy system will supply largely carbon-free power. This change of strategy reflects not only climate protection concerns but also imperatives regarding security of supply, industrial competitiveness and social sustainability. In order to accelerate the transition to a sustainable energy system, the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG was established at the beginning of 2020. This incorporates the International Geothermal Centre Bochum (GZB) along with two newly created branches: one in Cottbus, focusing on energy infrastructures; and one in Jülich, focusing on sector coupling. These three locations form a link between the regions most affected by structural change in both eastern and western Germany. Fraunhofer IEG will also conduct research at branch labs in Weisweiler, near Aachen, and in Zittau. In order to achieve the transition to a sustainable energy system, it will be necessary to couple infrastructure in the electricity, district heating and transport sectors. Only then does it become more feasible to incorporate renewables in the energy mix and thereby reduce carbon emissions. In particular, geothermal energy has the potential to play a key role in the future energy system. This is because it can be used to top up the energy supply to district heating networks.

Fraunhofer IEG will focus on the following fields: energy system infrastructure and sector coupling, heat mining and heat storage, borehole systems, geo-resources and development of the requisite technology, energy systems, and carbon sequestration. The International Geothermal Centre Bochum (GZB) forms a key part of Fraunhofer IEG. At the same time,

the branch lab in Aachen will conduct R&D in the use of geo-resources and thermal and material-based energy storage systems. A large-scale lab to be established at the RWE power plant in Weisweiler will investigate deep-geothermal technology for the generation of heat, refrigeration and electricity. And the Open District Hub Research Center in Jülich will develop systems for sector coupling on the level of individual neighborhoods. A further branch lab of Fraunhofer IEG is being established in Cottbus, in the Lausitz region of eastern Germany. This will focus on energy infrastructure and, specifically, supply and distribution systems for district heating and gas. Together with the branch lab in Zittau, the Cottbus facility will investigate and develop the infrastructure required to couple district heating, electricity, gas and transport. Contributing its extensive experience and scientific expertise in the design and operation of large power plants will be the Brandenburg University of Technology Cottbus-Senftenberg. The branch lab in Zittau, meanwhile, will collaborate with the University of Applied Sciences in Zittau/Görlitz. This work will focus on energy technology and production systems for thermodynamic conversion systems.

Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS

The former Fraunhofer Project Group for Materials Recycling and Resource Strategies IWKS was established eight years ago under the aegis of the Fraunhofer Institute for Silicate Research ISC. Following a Senate decision of November 2019, this has become the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS as of 2020. Fraunhofer is delighted to have secured the services of Prof. Dr. Anke Weidenkaff, formerly of ETH Zurich, as director of Fraunhofer IWKS. She was appointed in April 2019. Fraunhofer IWKS employs around 90 people at its two locations in Alzenau (Bavaria) and Hanau (Hesse). Work focuses on the following fields: material flow management, urban mining,

biogenic materials, magnetic materials, energy materials and recycling analytics. The Alzenau location is to step up activities in the fields of digitalization and resource management, including the economic and ecological aspects of a circular economy. The Hanau location is cooperating with regional partners from industry to develop the use of recycled materials for applications in the field of electromobility, including batteries, fuel cells, lightweight parts, electric motors and power electronics.

Initiatives in artificial intelligence

KI.NRW, an AI competence platform

KI.NRW is an initiative launched by the state of North Rhine-Westphalia in the field of artificial intelligence. Its purpose is to promote close collaboration between business, trade unions and the scientific community. The initiative has already launched a number of flagship projects to support the transfer of new technology from research to industry. It is currently establishing test environments to enable exploratory investigation of the following areas: mobility, manufacturing, the circular economy, medical engineering and digital farming. KI.NRW is also collaborating with the European initiative AI4EU – A European AI On-Demand Platform and Ecosystem, which involves the participation of THALES. In parallel, its Data Science Learning Laboratory is focusing on developing AI skills in the business sector, in the areas of training and continuing education, and in society at large. Meanwhile, KI.NRW has already produced the first ever pan-European inspection catalog for the certification of AI applications. This enables a professional and neutral evaluation of AI applications and certifies not only that they are technically reliable but also that they utilize AI in a responsible way. The catalog was produced in cooperation with Germany's Federal Office for Information Security (BSI) and drawn up by a team of researchers from the Universities of Bonn and Cologne and from the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS.



A number of stakeholders in the International Data Spaces initiative are located in North Rhine-Westphalia. The aim of this initiative is to establish a secure data space that will enable companies to retain control of their data assets. There is also important cooperation in this area with the Competence Center Machine Learning Rhine-Ruhr (ML2R), led by TU Dortmund University and Fraunhofer IAIS. ML2R is one of four national nodes for advanced research and technology transfer in the area of machine learning.

Fraunhofer Center for Cognitive Production Systems (CPS)

The creation of the Fraunhofer Center for Cognitive Production Systems (CPS) has provided the Chemnitz and Dresden region with an interdisciplinary platform that marries mechanical and production engineering with microelectronics and IT. By combining traditional with innovative production processes, it aims to keep pace with the structural change now taking hold in the value chains of international manufacturing. SMEs, in particular, will welcome the combined offer of technological and systems-related expertise, comprising AI tools and AI algorithms. This will help them develop new services and business models, thereby strengthening Saxony's standing as a technology location.

Flexible process chains are one of the key drivers of the paradigm shift in manufacturing. This requires the use of, for example, smart microsystems for production machinery and plant. One of the tasks of Fraunhofer CPS will be to connect such systems, create digital twins, and utilize cognitive systems to manage and control these smart processes. The new center is located at the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz and Dresden.

Center for Explainable and Efficient AI Technologies – CEE AI

The Center for Explainable and Efficient AI Technologies – CEE AI was established in 2019, initially in a virtual form. It focuses on two fields: explainable AI, with an emphasis on knowledge engineering; and efficient AI, with an emphasis on high-performance computing, big data and efficient incorporation of AI algorithms in company hardware systems.

As a regional hub for this kind of research, the CEE AI will help strengthen the mechanical engineering and microelectronics sectors, for example, both of which are strongly represented in Dresden. The CEE AI is a joint venture of TU Dresden and the Fraunhofer-Gesellschaft. TU Dresden is represented by the Center for Tactile Internet, a TU Dresden cluster of excellence, and by other professorial chairs. Fraunhofer is represented by the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS, for Machine Tools and Forming Technology IWU, for Integrated Circuits IIS (Division Engineering of Adaptive Systems EAS) and for Transportation and Infrastructure Systems IVI.

Research and Innovation Center for Cognitive Service Systems (KODIS)

The Research and Innovation Center for Cognitive Service Systems (KODIS) is located on the Bildungscampus Heilbronn. It was established by the Fraunhofer Institute for Industrial Engineering IAO with the financial support of the Dieter Schwarz Stiftung. In developing data-based business models that provide customers with individual benefits and added value, the new center is seeking to respond to the impact that digitalization and AI processes will have on value chains. KODIS focuses on not only established service sectors such as commerce, logistics and the energy industry but also on production-related services. The aim is to provide the region's



high proportion of small and medium-sized enterprises as well as family-owned/owner-operated companies with easy access to solutions for dealing with data and AI processes. In addition, a Collaborative Service System Engineering and Simulation Lab (CS3-Lab) is to be established. For this purpose, high-performance computer infrastructures and visualization technologies are being developed in Heilbronn and Stuttgart. These will be used to analyze, simulate and develop the processes and decision-making patterns required for complex service systems. The Technical University of Munich and Heilbronn University of Applied Sciences are involved in this project.

Advanced AI Center for Learning Systems

The Fraunhofer Institutes for Industrial Engineering IAO and for Manufacturing Engineering and Automation IPA have established an Advanced AI Center for Learning Systems. Created with the help of public funding, this new facility will provide a focal point for applied AI research for small and medium-sized enterprises. The center joined the Cyber Valley project at the end of 2019. This is Europe's largest research collaboration in the field of AI. Its founding partners include Amazon, automotive companies, the state of Baden-Württemberg, the Max Planck Society (Max Planck Institute for Intelligent Systems) and the Universities of Stuttgart and Tübingen. The Cyber Valley project also benefits from the support of renowned foundations.

AI Learning Lab for SMEs

Three Fraunhofer Institutes in Bonn have joined forces with the Fraunhofer Academy to set up an AI further training center at Schloss Birlinghoven campus. The purpose of the AI Learning Lab is to provide, first and foremost, small and medium-sized enterprises with assistance in developing and implementing their own AI use cases, together with appro-

appropriate training for their employees. To be able to exploit the disruptive potential of AI and profit from its economic benefits, companies first need to build up broad technical and human resources. The Fraunhofer AI Learning Lab employs a three-pronged approach: research, training and implementation. To this end, three research labs will be created: one for big data, one for predictive maintenance and one for AI on the edge. In parallel, the new facility will progressively establish a further-training program with courses ranging from the already existing qualification of Basic Data Scientist to the new qualification of Senior Data Scientist AI. The AI further training center is being established with the help of funding from the AI lab competition organized by the German Federal Ministry of Education and Research (BMBF). It involves the participation of the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS, for Algorithms and Scientific Computing SCAI, for Applied Information Technology FIT, and the Fraunhofer Academy.

"What's the IQ of AI?" – FUTURAS IN RES 1

The second edition of the FUTURAS IN RES series of scientific conferences brought together 320 high-ranking experts and guests from science, industry and other areas of the economy. In a total of five sessions featuring keynote addresses, panel discussions and live polls, the conference looked at the latest developments in AI and considered the changes and improvements it might bring in the future. All in all, some 30 speakers from Germany, the USA, Switzerland, France and countries in Asia offered insights into the current state of research and technology. In 2020, FUTURAS IN RES will focus on the topic of quantum technology.



Initiatives to promote data sovereignty

International Data Spaces, German Edge Cloud, GAIA-X, European data sovereignty initiative 2

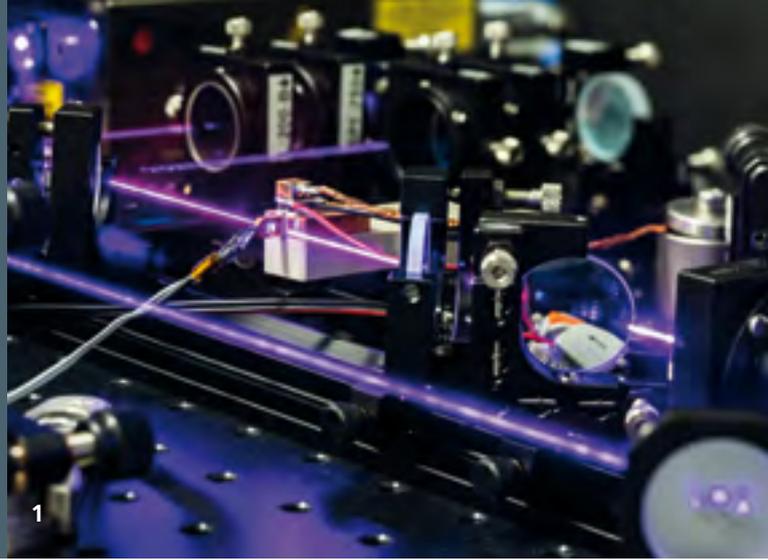
Smart manufacturing presents companies with huge challenges, not least the question of how to manage data-driven production processes in real time. In response, Fraunhofer has teamed up with partners from industry to develop smart solutions for this sector. These partners include the start-up company German Edge Cloud GmbH, which is part of the Friedhelm Loh Group and has given its name to the project. The idea is to combine the benefits of cloud computing with those of edge computing. While cloud computing delivers maximum scalability in computing and data storage, edge computing enables local processing of large volumes of data in real time. The first fruits of this project were delivered in 2019 with the market launch of the industrial edge cloud appliance ONCITE. Key to this development is a software architecture developed by Fraunhofer for the International Data Spaces (IDS) project, which was funded by the German Federal Ministry of Education and Research. This creates a secure data space enabling users to retain control over data storage and data transfer with partners.

Currently preparing for launch is a follow-on project by the name of Fraunhofer Edge Cloud. Some 20 Fraunhofer Institutes are to build a unique network of living labs for edge cloud computing, thereby creating an attractive platform for further collaboration with industry. A common feature of the German Edge Cloud and the Fraunhofer Edge Cloud is that all the nodes for both will be paired with local 5G campus networks. Local nodes will therefore be able to exploit this forthcoming standard for cellular networks and thereby provide real-time solutions for mobile applications on company sites.

Given the relevance of these joint developments – and their advanced technological maturity – Fraunhofer and German Edge Cloud GmbH were also able to play a key role in designing GAIA-X. This proposed solution to ensure data sovereignty and data availability for Europe was unveiled at a Digital Summit held by the German federal government in Dortmund at the end of 2019. Together with European partners, representatives from federal government, industry and science are working to create a secure and connected data infrastructure that guarantees digital sovereignty and fosters digital innovation on the basis of interoperability. This project provides a platform for an open and transparent digital ecosystem in which data and services can be made available, merged and securely shared, thereby enabling a ready commercialization of digital services. GAIA-X is also intended to form the nucleus of a European data sovereignty initiative. As such, it will enhance control over data storage and data use through the future addition of trustworthy hardware and physically secure communications based on quantum technology.

From brown coal to blockchain in the Rhineland

In a project funded by the state government of North Rhine-Westphalia, Fraunhofer has established a Blockchain Living Lab in the former Rhineland coalfields. Inaugurated in September 2019, the lab is to test practical blockchain applications and relevant business models for areas of business common to the Rhineland: energy, logistics, supply chain management, public services, financial services and Industrie 4.0. In addition, the lab will trial and validate new technologies and business models in partnership with relevant stakeholders in North Rhine-Westphalia. The project consortium comprises the Fraunhofer Institutes for Applied Information Technology FIT (Bonn), for Material Flow and Logistics IML (Dortmund) and for Technological Trend Analysis INT along with RWTH Aachen University, Ruhr University Bochum, the University of Applied Sciences Gelsenkirchen and the company regioIT GmbH.



Initiatives to promote quantum technologies 1

Germany occupies a strong position in the field of quantum physics and first-generation quantum technologies. Applications here include laser devices, quantum computers and MRI appliances. The second quantum revolution will exploit quantum effects to deliver novel imaging techniques and sensor systems capable of rendering physical data to a resolution and clarity never before achieved. It should bring major changes or even disruptive innovations to a whole range of areas, including medical engineering – e.g., surgical navigation systems and enhanced diagnostic systems – and semiconductor manufacture. The advent of quantum communications and quantum computing will radically advance artificial intelligence, machine learning and data encryption as well render IT applications invulnerable to eavesdropping.

A national Fraunhofer competence network for quantum computing

A consortium comprising the following members is to establish a national Fraunhofer competence network for quantum computing: the Fraunhofer Institutes for Applied and Integrated Security AISEC, for Open Communication Systems FOKUS, for Intelligent Analysis and Information Systems IAIS, for Applied Solid State Physics IAF, for Industrial Mathematics ITWM, for Algorithms and Scientific Computing SCAI and for Secure Information Technology SIT. This consortium will bring together the disciplines of quantum computing, artificial intelligence and IT security. Together with IBM, it will also operate the first commercial quantum computer in Germany, as an open research platform for business-relevant questions.

Quantum photonics labs (QPL)

In 2018, the German federal government launched a framework program to take quantum technology from the basics to market launch. This program includes a joint strategic initiative by the Federal Ministry of Education and Research (BMBF) and the Fraunhofer-Gesellschaft on quantum imaging and quantum sensing. A total of 11 Fraunhofer research units are participating. The aim is to increase research knowledge in this field and to develop applied technology for the purpose of close collaboration with industry. In line with the federal program, work commenced in May 2019 to establish a set of quantum photonics labs (QPL) at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena. This will create a transfer center for universal applications of quantum-optical technology. This new center will focus on finding new ways for industry to make use of quantum light sources and other key components of this technology. It offers a prime example of how to meet the strategic goal of creating a national infrastructure of application laboratories – for, and in collaboration with, partners from industry and research. It was the QPL initiative, along with Fraunhofer IOF's participation in the Thuringian Innovation Center for Quantum Optics and Sensors (InQuoSens), that prompted the BMBF to entrust Fraunhofer IOF with the task of coordinating QuNET, a major initiative to create a quantum communications network that is immune to eavesdropping.

QuNET

The purpose of QuNET is to enable secure communications between government organizations. The seven-year project provides a central platform for the creation of a German quantum communications infrastructure and marks a major step towards development of the quantum internet. On the European level, the German federal government and QuNET

consortium partners are seeking to create a secure European data space. QuNET will lay the foundations for establishing a unified and secure information and communications infrastructure for Europe. The long-term plan is to link this quantum-based communications infrastructure with the International Data Spaces project in order to attain the highest level of data sovereignty and data security for European data space.

The project is being led by the Fraunhofer Institute for Applied Optics and Precision Engineering IOF (Jena) and by the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI (Berlin), in partnership with the German Aerospace Center (DLR) and the Max Planck Institute for the Science of Light (Erlangen). It also involves industry partners from the following sectors: telecommunications, security, satellite operation, and systems and component design. This cooperation will ensure rapid transfer of the technology developed for the QuNET project. The project officially began in fall 2019 and comprises three phases. Researchers will first develop the hardware components and then establish the technological foundations for multi-user operation in heterogeneous networks. In the third phase, they will work with industry and Germany's federal network providers to establish a quantum-based network for government agencies. This will take the form of a quantum-safe pilot link between federal agencies.

QuantumRISC

The advent of quantum computers will make it easier to crack current encryption methods than is now the case with conventional computers. This will therefore necessitate the development of new forms of data security that are proof against such attacks. Germany is one of the world's leading locations in the new research field of post-quantum cryptography (PQC). All newly developed PQC methods must be

tested to ensure they are workable and can be incorporated in existing systems. In QuantumRISC, a project led by the Fraunhofer Institute for Secure Information Technology SIT, partners from industry and science are investigating how embedded systems, especially in autonomous vehicles, can best be protected against such attacks. For this purpose, the consortium partners are developing special PQC methods that combine stringent security with minimal energy consumption and data-storage requirements.

Initiatives for the hydrogen economy

Hydrogen technology has a key role to play on the road to a carbon-neutral economy. It can deliver solutions that pave the way for further development of renewable energy, climate-neutral industrial processes and sustainable mobility. For Germany, hydrogen technology offers the chance to maintain a manufacturing industry and to develop new export opportunities. In 2019, Fraunhofer established a Hydrogen Network, which enables us to respond rapidly to the needs of industry and society. This network pools the experience and expertise of 22 institutes (as at December 31, 2019) along the entire value chain of the hydrogen economy. A number of Fraunhofer Institutes have launched projects designed to demonstrate the viability of this technology. Others are members of consortia or other ventures such as the living labs funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) or regional initiatives established to combat the impact of structural change. The Hydrogen Network has also produced a hydrogen road map for Germany as a discussion paper for the German federal government's national hydrogen strategy.

HyFab – research project to develop production-ready fuel cell applications

In order to meet climate-protection targets, we also need to reform the transportation sector. As a potential source of power for electric vehicles, the hydrogen-powered fuel cell offers an alternative or supplement to battery technology. To achieve the volumes required, it will be necessary to upscale current production capacity by around three orders of magnitude. The Baden-Württemberg State Ministry of the Environment has therefore provided 7.9 million euros to fund further research into fuel cell production. The HyFab project will define the requisite quality specifications at each stage of the process chain and develop training courses and workshops in order to expedite the transfer of know-how to industry. The two project partners are the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), which is coordinating the project, and the Fraunhofer Institute for Solar Energy Systems ISE. They will consult with a steering group from industry. In enabling machinery and plant manufacturers to benefit from joint and contract research, and quality assurance, the HyFab project will help smooth the transition to future mass production.

Lighthouse projects

Lighthouse projects are strategic initiatives that mark out specific fields of research within our overall portfolio. Our institutes pool their expertise in one or more of these research fields in order to roll back the frontiers of technology and take on the challenges currently facing society and the economy. Each of these scientific consortia works for around four years in order to develop fundamentally new technological approaches that will help to preserve Germany and Europe's innovative edge.

Go Beyond 4.0 – conserving resources and cutting costs, from unique items to mass production 1

In order to meet the demand for increasingly customized products, sectors such as automotive or aircraft construction are going to need new modes of production. Digital printing and laser processing techniques geared up for mass production will enable the manufacture of increasingly customized variants of series products all the way down to unique items. Thanks to a combination of conventional and digitally controlled manufacturing methods, this will also conserve resources, cut costs and increase the rate of production.

Using digital printing and laser processing techniques, a Fraunhofer consortium has been able to produce printed circuits and sensor components incorporated within complete parts. In the case of a car door, for example, this obviates the need to fit a cable tree. Here, the copper wiring to power the small motors for the side windows is applied directly to the door – including a covering of insulation material – by means of an industrial robot. For an aerospace project, engineers incorporated sensors and other elements within the fiber-reinforced composite material used to make an aircraft wing. This included sensors to record variables such as temperature or deformation; signaling circuits; and even heated wires to keep the wing free of ice without the need for chemical de-icing. In order to test their electronic reliability, the elements were placed in a shaker and subjected to forces many times greater than gravity. The Go Beyond 4.0 project was launched at the end of 2016 and involves the participation of the Fraunhofer Institutes for Electronic Nano Systems ENAS, for Manufacturing Technology and Advanced Materials IFAM, for Laser Technology ILT, for Applied Optics and Precision Engineering IOF, for Silicate Research ISC and for Machine Tools and Forming Technology IWU. In 2020, it is focusing on process stability and product reliability.



Electrocaloric heat pumps – climate-friendly and no harmful refrigerants

According to the German Environment Agency, over half the energy consumed in Germany goes on either heating or refrigeration. This means that the transition to a sustainable energy system can only succeed if a technology can be found that requires less energy and is less harmful to the climate than the majority of the current generation of compressor systems. The refrigerants in these systems are bad for the environment and human health. They pose a fire hazard and are frequently ineffective. Moreover, the compressors themselves are often noisy.

The ElKaWe lighthouse project focuses on the electrocaloric effect, a well-known phenomenon first described in the 1950s. A consortium of six Fraunhofer Institutes is investigating the development of ceramic and polymer-based electrocaloric materials from cheap and harmless starting materials. These will provide the basis for an entirely new and much more efficient type of heat pump/refrigeration system, without the need for compressors and ozone-depleting refrigerants. Researchers are hoping to substantially boost the efficiency of the heat pipe used for this purpose. If all goes to plan, they will have a demonstrator with an output of 100 watts and a temperature range of 30 degrees Kelvin within the space of four years. The project involves the participation of the Fraunhofer Institutes for Physical Measurement Techniques IPM, for Ceramic Technologies and Systems IKTS, for Applied Solid State Physics IAF, for Applied Polymer Research IAP, for Structural Durability and System Reliability LBF and for Organic Electronics, Electron Beam and Plasma Technology FEP.

MaNiTU – solar cells with extremely high conversion efficiency

MaNiTU is another lighthouse project that aims to ease the transition to a new energy economy. In order to achieve climate targets, the proportion of power generated by photovoltaic systems will have to increase worldwide. A consortium of six Fraunhofer Institutes is therefore seeking to exploit a paradigm shift in materials and technology so as to improve the efficiency of photovoltaic cells – together with the associated power-generation costs – and also reduce their environmental footprint. It is hoped that this will help regain some of the market share lost to Asia. The consortium is working to develop tandem solar cells that do not require the use of problematic materials. Tandem solar cells are highly efficient on account of their ability to exploit a larger proportion of the spectrum of sunlight. This will mean that now negligible surfaces such as car roofs will become attractive for the generation of solar power. In a lab environment, researchers have already achieved impressive improvements in efficiency with perovskite solar cells. The big drawback with this emerging technology is that the materials conventionally used for sunlight absorption and for contact and passivation layers – in particular, lead – fail to fulfill sustainability, market acceptability and market access criteria. Fraunhofer researchers are therefore using techniques from the materials sciences in order to identify and design new and nonhazardous absorber materials. Further objectives include minimal environmental impact, low costs and long-term stability.

The project involves the participation of the Fraunhofer Institutes for Solar Energy Systems ISE, for Silicate Research ISC, for Mechanics of Materials IWM, for Surface Engineering and Thin Films IST and for Microstructure of Materials and Systems IMWS along with the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS. This consortium brings together Fraunhofer expertise in the theoretical and experimental material sciences and in the technological, commercial and environmental aspects of solar cell technology.

SWAP – hierarchical swarms for enhanced production

If digital manufacturing, with its reliance on connected logistics and cyberphysical systems, is to become more effective than conventional manufacturing, then it will need to move beyond a traditional production environment in which goods are made at assembly stations in a predefined sequence of processes. The trend towards greater customization, driven by increased digitalization, necessitates a high degree of flexibility in production capacity. The consortium behind the SWAP lighthouse project is working to create an autonomous and highly flexible production environment based on the model of a hierarchical swarm. This means organizing mobile manufacturing units, machine tools, production machinery and transport vehicles in such a way as to create a flexible production environment that can adapt the process chain to new requirements and autonomously find the most efficient usage of production capacity. The institutes participating in the project are seeking to identify agile manufacturing approaches that can be adapted to a range of operational issues.

Fraunhofer researchers are also seeking to combine swarm intelligence with federated learning. In this approach, data stored on local edge nodes is used to create global AI models that make the swarm as a whole more dynamic. Using this kind of knowledge-based, preventive control (learning from similar scenarios), it is possible to build resilient and dynamic infrastructures that deliver high productivity and greater scope for customization. The project involves the participation of the Fraunhofer Institutes for Applied Optics and Precision Engineering IOF, for Factory Operation and Automation IFF, for Intelligent Analysis and Information Systems IAIS, for Laser Technology ILT, for Material Flow and Logistics IML, for Physical Measurement Techniques IPM, for Manufacturing Engineering and Automation IPA, for Material and Beam Technology IWS and for Machine Tools and Forming Technology IWU.

National centers

ATHENE 1

The National Research Center for Applied Cybersecurity ATHENE (formerly CRISP) is Europe's largest research center for cybersecurity and data privacy. ATHENE represents a unique form of collaboration in the field of university and non-university research. It investigates key issues in relation to cybersecurity and the protection of data privacy – and provides corresponding support for business, the public sector, company founders and start-ups. ATHENE is a research facility established by the Fraunhofer-Gesellschaft. It involves the participation of the Fraunhofer Institutes for Secure Information Technology SIT and for Computer Graphics Research IGD along with the Technical University of Darmstadt and Darmstadt University of Applied Sciences. ATHENE is located in Darmstadt and is funded by the German Federal Ministry of Education and Research (BMBF) and the Hessian State Ministry for Higher Education, Research and the Arts (HMWK).

ROBDEKON – robotic systems for decontamination in hazardous environments

Remediation of old landfill sites, sorting toxic waste, dismantling nuclear facilities – despite stringent safety precautions, such tasks expose people to substantial hazards. An alternative is to let robots and autonomous machinery take on this work. Opened in June 2019, ROBDEKON is one of two competence centers in a Federal Ministry of Education and Research (BMBF) program of research in civil security. The center has already demonstrated several scenarios, including excavation work performed by a computer-controlled mini-excavator. In another application, a robot picks up a piece of plant, inspects it from various angles, cleans it and then places it ready for disposal.



The ROBDEKON project is coordinated by the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB in Karlsruhe. Further research partners are the Karlsruhe Institute of Technology (KIT), the FZI Research Center for Information Technology, also located in Karlsruhe, the German Research Center for Artificial Intelligence (DFKI) and a number of industrial companies. ROBDEKON provides consultation on all issues regarding decontamination with robots.

German Rescue Robotics Center (A-DRZ)

The German Rescue Robotics Center (A-DRZ) commenced operation in 2019. Located in Dortmund, it is the second of two competence centers in the Federal Ministry of Education and Research (BMBWF) program entitled Research for Civil Security. The new facility also features a living lab, located on the former industrial site of Phönix-West in Dortmund, which will trial the use of robots in support of emergency personnel in hazardous rescue operations. Four emergency scenarios will be investigated: fire, collapse and burial, detection of hazardous substances, and flooding. The establishment of the new center marks the first time ever in Germany that research, industry and the emergency services have collaborated to develop autonomous robots for use in rescue operations. A robotics task force to act on the national and international level is also being established. With its experience in organizing international robotics competitions, the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE is ideally placed to assist the new center in developing new scenarios to develop a requirements analysis for robotic systems and to determine their performance specifications.

PROJECTS AND RESULTS 2019

HEALTH AND ENVIRONMENT

Joseph von Fraunhofer Prize

Dental glass-ceramic: high-strength and quick to use 1

When a dental prosthesis becomes necessary, patients and dentists want a product that is colorfast and strong – and that can be individually customized very quickly. Dr. Bernhard Durschang and Dr. Jörn Probst from the Fraunhofer Institute for Silicate Research ISC developed the material, manufacturing process and pilot production line for such a dental prosthesis made from novel glass-ceramics in just under four years. The project encompassed everything from the inceptive idea to material development to the CI-certified production system – observing all necessary quality management requirements for medical devices. Fraunhofer ISC contributed two success factors to the breakthrough of the innovative dental restoration materials: scientific excellence in the development of new glass materials and engineering innovation in building a glass-melting and casting facility for the production of dental glass-ceramic blocks.

This new development offers several advantages over conventional dental ceramics. The color and translucence of the dental prosthesis permit an ideal match with the patient's teeth – and can be changed so quickly and individually that patients can wait right in the dentist's chair. Despite the higher glassy phase content, these newly developed glass-ceramics proved to be at least on a par in terms of chemical stability, and even markedly superior in their mechanical properties, making the material suitable for modifications to molars, as well. The first innovative glass-ceramics, marketed by DeguDent and VITA under the product names Celtra® Duo, Celtra® Press and Suprinity®, have been in use in many dentists' offices since 2013.



Alternatives for antibiotic resistances

Today, some 700,000 people worldwide die from multidrug-resistant pathogens each year. The latest report on the antibiotic resistance situation, from spring 2019, commissioned by the United Nations and the World Health Organization, warns of the consequences in the decades ahead if countries do not take action.

Back in 2015, Germany's federal cabinet approved a national antibiotics resistance strategy coordinated by several federal ministries. One approach consists in supplementing conventional antibiotic therapy in patient care with the bacteriophage treatment that is still widespread in Eastern Europe today. This treatment involves bacterial viruses that highly specifically detect, infect and destroy strains of a particular bacterial species. Unlike antibiotics, phages can mutate, which means that, like their hosts – the bacteria – they are adaptable. As active pharmaceutical agents, they must be highly specific against the respective bacterial species and be approved as drugs.

The biotechnology team at the Fraunhofer Institute for Toxicology and Experimental Medicine ITEM is involved in research projects in various consortia. Two of them were launched in 2019. With funding from the German Federal Joint Committee's innovation fund, a medical-scientific team began manufacturing individually matched phage preparations for hospital pharmacies. These preparations are used on arms and legs to treat surgical wounds infected with multidrug-resistant pathogens. Together with a drug manufacturer, the team is developing an inhalation cocktail from three bacteriophage strains against MRSA, a multidrug-resistant staphylococcus bacterium. Since this dreaded "hospital germ" is frequently found on healthy people, clinical interventions harbor a high risk of infection. Pretreatment with bacteriophages could prevent this. The Leibniz-Institut DSMZ – German Collection of Microorganisms and Cell Cultures GmbH is a cooperation partner in both projects.

Less and better fat for foodstuffs

One in every five deaths worldwide is reportedly connected to inadequate and unbalanced nutrition. This is the conclusion reached by a spring 2019 study conducted by "The Lancet", one of the world's oldest medical journals. Sandwich spreads often contain the ecologically and nutritionally problematic palm fat. The saturated fatty acids it contains can raise blood lipids, cholesterol and, ultimately, the risk of coronary heart disease. As alternatives, the Fraunhofer Institute for Process Engineering and Packaging IVV is developing ingredients with high-quality polyunsaturated oils from rapeseed and sunflower seeds. Before these can be used as fat substitutes, properties such as melting behavior and viscosity have to be adjusted, as these aspects are also very important in ensuring customer acceptance. To this end, the development team at Fraunhofer IVV crystallizes the oils to adjust the texture in a specific way, enabling them to obtain a more desirable fatty acid mixture without changing the total fat content.

Another Fraunhofer IVV project is aimed at reducing fat, for instance in sauces and in cream fillings for baked goods. Both of these initiatives are projects within the EIT Food innovation community, in which 50 leading companies, universities and scientific partners are working to transform the food value chain.



Keeping carbon in the cycle 1

By 2030, Germany aims to reduce its greenhouse gas emissions by more than half and to bring fewer fossil-based materials into the production cycle. At the same time, it expects the economy to continue to safeguard jobs and prosperity. This poses major challenges for energy-intensive key industries such as steel and chemicals. Carbon2Chem® is a pioneer project for the circular carbon economy, and is funded by the German Federal Ministry of Education and Research (BMBF). In a public-private partnership, the steel and chemical industries are collaborating with the energy industry and research organizations to implement a flexible carbon capture and utilization (CCU) concept for carbon-based industries. It is expected that innovations from the concept's six sub-projects will help cut annual CO₂ emissions in the German industrial and manufacturing sectors by 10 percent.

One of these sub-projects involves manufacturing basic chemicals or synthetic fuel from the steel mill gas produced during steelmaking. For methanol, for example, carbon monoxide, carbon dioxide and hydrogen are required. Currently, the carbon stems primarily from fossil sources. In a pilot plant at the Carbon2Chem® lab in Oberhausen, preparations have been underway since 2019 to implement industrial-scale production of methanol from steel mill gas. To do this, new requirements have to be taken into account through the composition, purity and temporal availability of steel mill gases. It is being tested, for instance, whether available catalysts function stably under the given conditions. Process simulations enable production to be optimized, also taking acceptable investments in upstream gas cleaning into account. Starting in 2020, plans foresee the relocation of the pilot plant from Oberhausen to Duisburg, to the Carbon2Chem® "Technikum," where it is expected to produce up to 75 liters of raw methanol daily from steel mill gases from the steel-

works there. The Carbon2Chem® lab in Oberhausen, which has around 500 square meters of lab space, is jointly operated by the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and the Max Planck Institute for Chemical Energy Conversion.

Wastewater without microplastics

Microplastics are everywhere. Wastewater treatment plants are facing the challenge of separating the tiny particles out of wastewater safely and without blockages. That is why the SimConDrill project is aimed at creating a durable filter that robustly and efficiently separates microplastics from wastewater. It is based on an already patented cyclone filter developed by mid-size company Georg Klass Filtertechnik and lined with special metal foils. The project partners use innovative laser technology to drill holes with a pore diameter of less than a hundredth of a millimeter, which allows for efficient filtering of particles as small as 10 micrometers, even with large quantities of water.

To manage the great flow of water, it is necessary to achieve as high a porosity as possible – that is, to provide as much filter area with drill holes as possible. To this end, the researchers at the Fraunhofer Institute for Laser Technology ILT are contributing their expertise in various areas. Ultrashort-pulse (USP) lasers are particularly suited for the tiny pore diameters. Experts will first develop the drilling process in the lab and then scale it to the LaserJob GmbH laser system. In advance realistic testing of the process parameters, material processing with USP is supported by process simulation in combination with optimization software from OptiY GmbH. Finally, for quality assurance, the specialists at Fraunhofer ILT and Lunovu GmbH monitor the drilling process: the characteristic radiation – known as process radiation – enables them to ascertain

2



whether all holes really are properly drilled through. A micro-plastics filter like this could also be used for cleaning ballast water, for mobile applications in sewer cleaning vehicles or for private households. The SimConDrill project, funded by the German Federal Ministry of Education and Research (BMBF) initiative for SMEs, was launched in 2019 and is set to run for two and a half years.

Catalysts for the climate 2

To turn CO₂ into a usable source of carbon for chemistry, the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB has developed a variety of materials, components and concepts: a patented catalyst synthesis and high-throughput screening for catalyst materials, electrochemical cells in which CO₂ is reduced with a catalyst on a porous gas-diffusion electrode, and combined (electro-)chemical-biotechnological processes. The most-produced organic feedstock, ethylene, has already been successfully manufactured from CO₂. An electrochemical demonstrator with a 130-square-centimeter electrode area accomplishes this in a single process step.

Methanol, too, has been obtained from CO₂ and electrolytically produced hydrogen. This platform chemical is becoming increasingly important for sector coupling, whether as a fuel additive for combustion engines or as an energy carrier in fuel cells. A patented method enables the researchers to assemble catalysts for synthesis from a wide array of elements and to optimize them using high-throughput screening. Copper proved to be a promising material for methanol synthesis. To increase value added, in a subsequent biotechnological fermentation, methanol can be transformed into more valuable chemicals that could otherwise only be obtained through complex, multi-stage syntheses.

Starting in 2020, an electrolysis platform sited at the Leuna chemical complex and jointly operated by the Fraunhofer Center for Chemical-Biotechnological Processes CBP and the Fraunhofer Institute for Microstructure of Materials and Systems IMWS will facilitate electrochemical synthesis on a near-industrial scale. The SynLink project is aimed at showing that renewable energy can be used to manufacture – through adsorption from the air – first syngas and, ultimately, methanol and fuels from H₂O and CO₂. Funding is provided by the German Federal Ministry for Economic Affairs and Energy (BMWi).



COMMUNICATION AND KNOWLEDGE

Joseph von Fraunhofer Prize

The fiber-optic expansion challenge: Fast Internet, planned in just days 1

The German federal government plans to roll out gigabit networks nationwide by the end of 2025. Such a plan can only be realized by expanding existing fiber-optic networks. The cable route planning processes this entails are highly complex and nearly impossible to manage with conventional methods, so Deutsche Telekom AG commissioned the Fraunhofer Institute for Physical Measurement Techniques IPM to develop an application. A survey vehicle gathers geo-mapping data, and cloud-based software is used to automate, interpret and classify that data. To achieve this, Prof. Dr. Alexander Reiterer, Dominik Störk and Dr. Katharina Wäschle realized for the first time an efficient and more reliable digital process with optical measurement technology and automated data analysis. A laser scanner captures a “preview” of entire streets, for which stacked 3D objects, such as a house wall behind a tree, must also be reliably resolved. In addition, data is fed into a color camera. The cloud-based software analyzes the two- and three-dimensional data fully automatically using deep-learning methods in a deep neural network. More than 30 object classes were used to train the algorithm, including vehicles, curbs, manhole covers, signs and trees. The software recognizes application-specific objects and incorporates their information in digital planning maps.

This revolutionary tool can be used anywhere objects and surfaces need to be captured and identified with centimeter accuracy. With it, Deutsche Telekom can not only plan fiber-optic cable routes up to 70 times faster than is currently possible, it can do so fully automatically and with a far greater level of detail. Soon, more than 1800 civil engineering companies in Germany will use the data generated by the Fraunhofer process chain to expand the fiber-optic network.



Quantum magnetometry for medicine 2

The development of the world's first laser threshold magnetometer is set to open new doors for research. It would enable the measurement of minimal magnetic fields generated, for example, by heart and brain waves or in neural networks.

MCG (magnetocardiography), MEG (magnetoencephalography) and MRI (magnetic resonance imaging) are established medical diagnostic methods based on magnetic field measurement. Currently, the only way to achieve greater precision is with highly sensitive magnetic field sensors, which normally work at extremely low temperatures. To enable biocompatible, ultra-sensitive laser threshold magnetometry to be used at room temperature, a group of junior researchers at the Fraunhofer Institute for Applied Solid State Physics IAF is combining the latest findings in quantum physics with those in materials science. As the laser medium, the physicists want to use a material with optically detectable magnetic resonance, as the stronger signals and higher contrasts this produces will allow them to obtain more precise measurement results. To achieve this, diamond laser crystals with a high density of atomic nitrogen-vacancy centers (NV centers) are being developed.

In 2019, the researchers were primarily investigating optimized laser crystals – the basis for the world debut of the laser threshold magnetometry approach. The second phase of the planned five-year project is aimed at realizing the laser system and conducting initial measurements – together with physicians and a medical device manufacturer. The DiLaMag project is funded by the German Federal Ministry of Education and Research (BMBF) through the NanoMatFutur competition for junior researchers.

German-made voice assistants

Alexa, Siri and the like can be more than just valuable helpers in everyday life: they open up great potential for companies to facilitate human-machine interaction and offer new services. Using the latest conversational AI methods, the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, in cooperation with the Fraunhofer Institute for Integrated Circuits IIS and in connection with the Fraunhofer Cluster of Excellence Cognitive Internet Technologies CCIT, developed a new dialog system for domain-specific knowledge. With technologies from machine-learning, question answering and intelligent knowledge networking using knowledge graphs, it differs from established services and is intended especially for use in industry. The system is customized for domain-specific knowledge and trained for certain fields of application, from voice-controlled customer service in call centers to dialog-based support for legal questions in management consultancies. It is capable of processing complex content and creating semantic links and is the leading system in the German-speaking countries when it comes to recognition rate and semantic interpretation.

The first demonstrator, a virtual city guide through Berlin, was created in cooperation with VW. Its interactive dialog system answers questions about the surrounding area. The smart vehicle voice assistant is one example of how companies can use dialog systems to enable intuitive interaction with technology and to develop new business models. In the SPEAKER project sponsored by the German Federal Ministry for Economic Affairs and Energy through its "Artificial Intelligence as a Driver for Economically Relevant Ecosystems" innovation competition, Fraunhofer IIS and Fraunhofer IAIS are further expanding these technologies and working with numerous partners on a German-made voice assistant platform.



Securely connecting millions of robots 1

According to a survey conducted by the International Federation of Robotics (IFR), more than 3.7 million industrial robots are expected to be in use in factories worldwide in 2021. Connecting, controlling and maintaining these robots poses significant challenges for industry. Secure and near-real-time communication with and between the machines at production sites is essential to achieving this. One solution is to deploy local and private 5G networks in combination with edge computing infrastructure.

Rittal, together with German Edge Cloud (GEC) and the Fraunhofer Institute for Open Communication Systems FOKUS, realized just such an application scenario in a control cabinet setup. A two-armed industrial robot attaches a conductor connection clamp to a busbar and inserts a cable into the clamp. The robot is controlled by means of virtual-reality controllers connected to an edge-based 5G core network via radio cells. An optical and acoustic signal indicates whether the task was performed successfully.

The network infrastructure is based on Open5GCore, which was developed by Fraunhofer FOKUS and is one of the world's first standards-based and manufacturer-independent 5G core networks. The modular, virtualized core network software lets users flexibly combine network functions for optimum application support on edge clouds, such as the German Edge Cloud. Because the network is implemented as software, network functions can be dynamically combined to form a customized, virtual, special-purpose network based on the required latency time, security level and number of devices to be connected. Network functions can even be dynamically adjusted during operation to account for usage behavior. In addition, the various integrated access-network and backhaul technologies permit adaptation to local requirements.

Open up aeronautics research?

Strengthening Europe's competitiveness and harnessing the potential of open science are stated aims of the European Commission. As a key element of the European research landscape, aeronautics research in particular has a major socioeconomic impact due to its inherent transdisciplinary nature and its relevance to society. Fraunhofer is making an important contribution to this effort with its EU project "OSCAR – Open ScienCe Aeronautic & Air Transport Research," launched in 2019. The project involves seven partners in investigating how the advantages of open science can be implemented in European aeronautics research and in the transportation industry.

For aeronautics research and the transportation sector, which particularly frequently rely on confidentiality agreements in dealing with intellectual property, the project is an ambitious one. Its goal is to align open science methods with conventional contractual provisions. To achieve this, the partners first analyze the potential and the challenges involved in opening up aeronautics and air transport research. In the second step, they will develop an Open Science Code of Conduct that is compatible with prevalent project agreements. Especially in early stages of technological maturity, the open exchange of knowledge offers many benefits. First, open science can boost the quality of research results, for instance through transparency or reproducibility. Second, open science can also help shorten innovation cycles.



The OSCAR project is coordinated by the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM. The Fraunhofer Research Services & Open Science Competence Center at the Fraunhofer Information Center for Planning and Building IRB in Stuttgart is contributing its open science expertise to the project, analyzing existing legal frameworks and developing the Open Science Code of Conduct. At the end of the project, this code of conduct is to be implemented in the aeronautics research community.

Hugo Geiger Prize

Decoding how artificial intelligence makes decisions 2

Machine learning is one of the most common methods for equipping machines with capabilities that resemble intelligent human behavior. By repeating tasks, the machines – aided by algorithms – learn to achieve predefined quality criteria better and better. One method is the black box model, in which the algorithm for the physical model with the problem to be learned is largely unknown.

In his dissertation, which was awarded summa cum laude, Dr. Sebastian Lapuschkin, a postdoctoral student at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, focused on explaining decision-making processes used by AI systems in individual model predictions. To do this, the computer scientist used layer-wise relevance propagation (LRP) to develop both a method for explaining individual model decisions and a methodological framework for systematically analyzing the general behaviors and predictive strategies the AI system has learned. With his methods and techniques, Lapuschkin coined the term “Clever Hans behavior” in AI research to describe ostensibly correct predictions made on the basis of unintended or incorrect decision-making processes. Due to their lack of transparency, black box models were previously subject to technical, ethical and legal limitations – especially in applications where security is vital, such as autonomous driving and (bio-)medicine. Lapuschkin’s techniques now make it possible to verify or reject AI decisions, thus paving the way for new areas of application.

PROTECTION AND SECURITY

The multimedia detectives

In May 2019, the German magazine "DER SPIEGEL" and the "Süddeutsche Zeitung" newspaper received secretly recorded video footage. A few days after its publication, Austria tumbled headlong into a government crisis over the "Ibiza video." The journalists were faced with the question of whether they could use the footage for their work or whether they had been given fake material. To clarify this, the research team turned to one of the world's premier institutions: the National Research Center for Applied Cybersecurity ATHENE (formerly known as CRISP) in Darmstadt, in which the Fraunhofer Institute for Secure Information Technology SIT is also involved. Five specialists from Fraunhofer SIT spent a week evaluating the video. First, using algorithms they had programmed themselves, they ran an automated check to detect any data anomalies in the video's resolution, sampling rates and frequency responses. They also checked whether the interior shots in the villa matched photos of the property in Ibiza by reproducing the camera angles and gauging objects for comparison. In response to this incident, Prof. Dr. Martin Steinebach, a computer scientist and head of the Media Security and IT Forensics department, made it clear that photos and videos can serve as weapons in today's information age. He recommends firmly establishing new infrastructures in the media industry to make the digital pathway from capture to publication transparent.



Operations control and communication system for police task forces 1

Since 2003, researchers at the Fraunhofer Institute for Transportation and Infrastructure Systems IVI have been cooperating closely with users to develop solutions for civil security with a focus on control and communication systems, and to translate these solutions directly into practical use. Their partners and users are police, fire department, emergency service and disaster management decision-makers and personnel. To successfully manage the practical challenges of fighting terrorism and crime, since 2013, Dr. Kamen Danowski from Fraunhofer IVI and Frank-Michael Löst from the Saxon State Office of Criminal Investigations (LKA) have been heading up the development of the “SE network” – the operations control and communication system for police task forces (“Spezialeinheiten,” or SE for short).

The SE network provides state-of-the-art web and server technologies in connection with mobile applications and assists police task forces with operations preparation, operations control and communication, and documentation, both in everyday operations and in large-scale emergencies. The system offers control modules for staff and mobile applications for police officers in the field. A key feature of the SE network technology is communication and coordination in operations across countries and authorities. The system has been in daily use since 2014 and is continually being expanded by the joint development team, which includes both researchers and police officers. The experience gained from using and analyzing future basic technologies forms the basis for the scientific and technological objectives for the system’s continuous refinement.

A multi-year research and development cooperation agreement was signed by the Saxon LKA and meanwhile 18 additional security agencies, stipulating the system’s immediate practical relevance and sustainable development. As a result of the high level of acceptance in the operations of the participating agencies, the “Standing Conference of Interior Ministers and Senators of the States” – AK II – Interior Security 2018 – unanimously decided to roll out the SE network as a national standard under the direction of the Federal Criminal Police Office (BKA), and to develop it further under the name EKUS. Since mid-2019, in the context of another multi-year cooperation, Fraunhofer IVI has also been developing an innovative control and communication system for the standard police service based on components from the SE network/EKUS.

Hugo Geiger Prize Vaccines are becoming more sustainable 2

While doing her doctorate at the Fraunhofer Institute for Cell Therapy and Immunology IZI, molecular biologist Dr. Lea Bayer worked on two different approaches for new vaccine technologies. This work garnered her the Hugo Geiger Prize. Bayer’s genetic vaccine approach paved the way for protection against respiratory syncytial virus (RSV) infections. A gene shuttle introduces the vaccine into the body as DNA. Bayer used the shell (capsid) of non-human papilloma viruses to perform this task. These viruses “transport” the vaccine DNA into the body. Genetic vaccines are cost-effective to manufacture since, after transfer, the body produces the vaccine on its own and with rapid adaptability to frequently mutating pathogens.



In connection with a MAVO project, Bayer also collaborated with three other institutes on the innovative manufacture of so-called inactivated vaccines. Currently, inactivated vaccines, such as those against influenza and polio, contain pathogens that are killed by chemicals. The research team succeeded in manufacturing such vaccines, for instance against RSV, rapidly, reproducibly and without chemicals by means of electron radiation. In this process, accelerated low-energy electrons break up the pathogens' DNA or RNA; while the pathogen's genome is reliably destroyed, its external structure remains intact. Only this "skeleton" is needed to trigger the formation of the appropriate antibodies in the human immune system. This research initiative was supported by the Bill & Melinda Gates Foundation. The requisite irradiation facilities are now being developed with a licensee in the pharmaceutical sector. The genetic vaccine was successfully patented, and both projects have been published. During her doctoral studies, Lea Bayer participated in TALENTA speed up, a Fraunhofer funding program for women.

How to protect against Avalanches in cyberspace

The Avalanche botnet infrastructure caused total estimated damage of 100 million U.S. dollars worldwide. In May 2019, Europol and a number of law enforcement agencies gathered in The Hague to present the findings of investigations from nearly 40 countries: more than ten suspects from around the world were brought to trial for organized computer fraud and money laundering. It also became clear that the authorities must continue to jointly operate the prevention infrastructures established by Fraunhofer security experts.

In analyzing and preventing cyber attacks, the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE has proven to be a key partner to national and international investigative authorities. Their analysis of infrastructure and malware since 2012 helped expose Avalanche and provided the evidence needed for criminal prosecution. At Fraunhofer FKIE – acting on behalf of Germany's Federal Office for Information Security (BSI) – a specially developed provider information system extracted victim data and sent around five million warnings to providers whose customers had been affected so those customers could clean up their computers.

Particularly the sinkhole servers developed and operated by Fraunhofer FKIE, along with the associated software, helped in this context and generally help protect individuals and companies around the world. These sinkholes redirect connection requests from infected computers to special servers. During peak periods, the Fraunhofer FKIE sinkholes were being contacted by 1.4 million infected systems per hour. The international collaboration will be continued, particularly where the sinkholes are concerned. This will prevent the botnet infrastructure from being reactivated by any unknown parties who might still possess the Avalanche program code.

Transporting hydrogen safely and efficiently 1

Hydrogen can be a major key to reducing CO₂ emissions. The most common and lightest element in our universe is capable of uniting the electricity, mobility, heating and industrial sectors to achieve the transition to a new energy economy. Producing hydrogen with renewable energies and in large quantities can contribute significantly to defossilization – not only in (heavy goods) traffic, but also in basic-industry processes.



To efficiently store and transport this energy source, the Fraunhofer Institutes for Microstructure of Materials and Systems IMWS and for Mechanics of Materials IWM have partnered with Hexagon Purus GmbH and RayScan Technologies GmbH to develop safe and lightweight high-pressure tanks. The tanks are designed to withstand operating pressures of up to 1000 bar to temporarily store and dispense highly compressed hydrogen – with up to 600 times more hydrogen per tank than in the uncompressed state and twice as much as in conventional pressurized vessels.

For the vessel's load-bearing structure, the partners use a fiber-reinforced hybrid composite plastic with an interior thermoplastic, gas-tight plastic liner. Metallic elements are attached to the ends of the tank. Some questions remain for operation at 1000 bar: how do materials react when the tank is filled or emptied, and how do they withstand extreme temperature fluctuations and other loads? Based on an understanding of the materials right down to their microstructure, the project partners want to develop an innovative macroscopic material damage model to reliably predict component behavior. They want to achieve 100 percent quality monitoring with the 3D X-ray inspection method to be used in the subsequent series production process for the hybrid-plastic pressurized vessels. This work is part of the HYPOS – Hydrogen Power Storage & Solutions East Germany innovation project. Funded by the German Federal Ministry of Education and Research (BMBF), the project involves more than 100 partners from business and academia working to lower the cost of hydrogen for the chemical industry, refineries, and the mobility and energy supply sectors.

Bomb-sniffer dogs in training 2

Research on explosives and their detection is one of the core competences of the Fraunhofer Institute for Chemical Technology ICT. Despite advances in technological systems, canine explosive detectors are the option of choice both for police and military task forces and for private security providers, thanks to their mobility and dependability. For this reason, they will continue to play an important role in detecting explosives in the future. In the national "EVADEX – Methods for the standardized evaluation of measuring systems for traces of explosives" project funded by the German Federal Ministry of Education and Research (BMBF), Fraunhofer ICT researchers most recently looked extensively at how the performance of technical solutions and of sniffer dogs can be evaluated for the respective requirements in different scenarios.

With the experience gained from numerous projects on explosives detection, the Fraunhofer ICT researchers developed scientifically evaluable training methods for the sniffer dog and handler teams. Their extensive offer includes different test scenarios for typical assignments. Dogs are trained using clean, uncontaminated explosives and homemade explosives, such as TATP. They can be conditioned to new substances at varying levels of difficulty on differentiation courses, but realistic scenarios involving vehicles, luggage racks and the like are also simulated to train both the dogs and their handlers. The institute also offers to conduct studies on sniffer dogs' olfactory abilities.



MOBILITY AND TRANSPORTATION

Basic report on Germany's blockchain strategy

In September 2019, the German federal government approved the blockchain strategy set out in the coalition agreement. A basic report on mobility and logistics that fed into this strategy was compiled by the Fraunhofer Institute for Applied Information Technology FIT on behalf of Germany's Federal Ministry of Transport and Digital Infrastructure.

Blockchain is the most prominent distributed ledger technology (DLT) and is used to document transactions – including, but not limited to, monetary ones. To put it simply, blockchain uses cryptographic methods to create a chain of transaction data. The most up-to-date copy of the blockchain is not stored centrally, but rather redundantly on the computers of those directly involved (peer-to-peer). This basic structure makes blockchain technology tamper-proof – any subsequent changes would be noticed immediately, rendering them unfeasible. This makes it possible to document and verify ownership and entitlements (assets). In the Internet of Information and the Internet of Things, this could only be done by using institutions such as a bank, an administrative body or some other trustworthy entity. Blockchain technology is thus enabling the shift toward the Internet of Value. The basic report addresses such key issues as fundamental technologies, economic principles and data protection. One conclusion is that, in principle, combined with other technologies, blockchain can lower costs and boost the efficiency and competitiveness of entire industries. In the experts' opinion, opportunities are opening up especially for mobility and logistics. Some of the applications the experts looked at included freight documents, electric vehicle charging, ridesharing and platooning.



Eyes for autonomous vehicles 1

A fail-safe sensor system will make autonomous vehicles even more reliable. A consortium of members from business and academia developed a combined camera-radar module designed to provide comprehensive protection for autonomous vehicles. Its reaction times are 50 times faster than standard sensor systems and 160 times faster than humans. This innovative electronics system consists of a camera and a radar sensor, combines the advantages of optical monitoring with radar technology, and uses integrated signal processing and machine learning to evaluate the collected data. The ultrafast response is achieved through sensor fusion and integrated signal processing. The data is processed and filtered directly in the module, and neural networks evaluate various traffic situations. Only instructions to react are sent to the vehicle, no status information. This frees up the vehicle's signaling bus to deal with urgent information, such as a child that suddenly runs out onto the road. The aim is to create a decentralized network in which these camera-radar systems can be flexibly connected with each other as well as with GPS and Car2X information. The Fraunhofer Institutes for Reliability and Microintegration IZM and for Open Communication Systems FOKUS also participated in the project, which was funded by Germany's Federal Ministry of Education and Research (BMBF).

Biomimetic synthetic rubber with the same properties as natural rubber 2

When particularly high standards are set for the dependability and structural durability of rubber components (for example in aircraft tires, construction vehicles and trucks), natural rubber is the material of choice. Until now, the properties of synthetic rubber have been inferior to those of its natural counterpart.

Natural rubber owes its until-now unrivalled performance to its pronounced tendency to crystallize in the stretched state – under load, the material can reinforce itself. However, a fungal disease that affects rubber trees is threatening the supply security of this natural resource.

An interdisciplinary Fraunhofer consortium that drove the development of a biomimetic synthetic rubber (BISYKA) inspired by nature has succeeded in optimizing the mechanical and tribological behavior of synthetic rubber. They identified key biological components, optimized the synthesis of functionalized polyisoprene with high microstructural purity, and used extensional crystallization measurements to test the characteristics of the resulting compounds. After achieving results comparable to natural rubber, the process was scaled up to manufacture 30-kilogram synthetic rubber samples. These were used to manufacture a set of BISYKA tires, which were compared with a reference set of four tires made from natural rubber. Lab tests conducted by Prüflabor Nord showed that tires made from the synthetic BISYKA rubber outperformed the natural rubber tires for the four evaluation criteria rolling resistance, dry grip, wet grip and wear. The positive scores for rolling resistance and wear are particularly good news, as the BISYKA tires lower fuel consumption, have a longer service life and produce fewer wear particles with the same mileage. In addition, the synthetic rubber can be produced on an industrial scale using existing machinery and equipment.

The Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ, a research division of the Fraunhofer Institute for Applied Polymer Research IAP, led the project consortium, in which the Fraunhofer Institutes for Microstructure of Materials and Systems IMWS, for Molecular Biology and Applied Ecology IME, for Mechanics of Materials IWM and for Silicate Research ISC also participated.



Car parts from biofibers 1

To lower CO₂ emissions, cars need to lose weight. However, demands such as improved safety resulting from more sensor technology, or better battery range in electric cars, currently tend to result in heavier vehicles. The Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI was looking for opportunities to use natural fibers and biopolymers in areas where the positive characteristics of carbon fibers are not required and the material properties of natural fibers can be leveraged. As sustainable alternatives across all life cycle phases, they opted to use vegetal fibers as components in bio-composite materials. With this biogenic content, fibrous materials made from flax, hemp, wood or jute not only improve the ecological balance, they are more economical to manufacture than carbon fibers and offer advantages in industrial processing, such as good acoustic damping properties and a low tendency to splinter, which is advantageous in the event of a collision.

These arguments were convincing enough to Porsche. In 2017, Porsche Motorsport and Fraunhofer WKI began working with the Four Motors racing team to test the bio-concept car. The experience gained in that process then informed material development for the parts of the new 718 Cayman GT4 Clubsport, the first series-produced car to feature body parts made from a biofiber composite. The driver and passenger doors as well as the rear wing are made of a novel composite material, in which a thermoset polymer matrix is reinforced with natural fibers that can easily be fit to part shapes. The new Cayman is a real lightweight, tipping the scales at 1320 kilograms.

The project is part of the German Federal Ministry for Food and Agriculture's "Renewable Resources" funding program via the Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V. – FNR).



2

So long, conveyor technology: The revolution of the logistics vehicle 2

The LoadRunner® high-speed vehicle offers the logistics sector a sustainable transportation technology. This innovative automatic guided vehicle can organize itself highly dynamically in swarms at up to 10 m/s – even linked to a platoon. The LoadRunner® is completely digitally embedded, allowing it to replace some parts of conventional conveyor technology. Thanks to artificial intelligence, it is capable of independently accepting and negotiating orders. Fully exploiting the potential of the LoadRunner® technology requires an open digital infrastructure in which the vehicles can communicate securely via 5G and independently conclude pay-per-use contracts using blockchain.

A LoadRunner® swarm was first introduced to the public at the Digital Summit 2019 conference in Dortmund. On the “digital platforms” information tour, the Fraunhofer Institute for Material Flow and Logistics IML also presented a bio-intelligent drone swarm, which essentially creates the basis for implementing high-speed applications in logistics. Through machine learning in a highly dynamic, three-dimensional system, the drone swarm develops bio-intelligent algorithms, which in turn efficiently control devices on the ground. With these two innovations, the LoadRunner® and the bio-intelligent drone swarm, Fraunhofer IML has made the platform economy of the future tangible. There, swarms of vehicles will organize themselves and communicate with humans as well as with other swarms and platforms to carry out their mission.

Charging points at the workplace

There were still 57 German cities that exceeded the air quality threshold value of 40 micrograms of nitrogen dioxide per cubic meter of air in 2018. In municipalities with particularly high levels of pollution, the collaborative “LamA – charging points at the workplace” project will establish a significant charging infrastructure for electric vehicles at Fraunhofer sites. The LamA project is part of the German government’s “clean air 2017-2022” immediate action program. The Fraunhofer Institute for Industrial Engineering IAO is heading up the project on behalf of Fraunhofer headquarters, with Stuttgart, Freiburg and Dresden serving as the project’s lighthouse locations. Seven institutes will pool their research activities and endeavor to make improvements in this area. Focus topics include secure IT solutions for implementing network-friendly charging, the impact of infrastructure provision on employee mobility behavior, and transferring experience in developing and operating the charging infrastructure to companies and municipalities.

All in all, the LamA measures are expected to save around 100 metric tons of nitrogen oxides annually. By 2022, 440 AC charging points (up to 22 kilowatts) and 44 DC charging points (up to 150 kilowatts) will be established at 18 Fraunhofer locations. The charging infrastructure is to be available to employees, vehicles of the Fraunhofer-Gesellschaft, and external third parties. In this way, the Fraunhofer-Gesellschaft is promoting environmentally compatible development of workplace mobility options at its nationwide locations, also for its own employees. The German Federal Ministry for Economic Affairs and Energy is funding the project with nearly 16 million euros. In addition, the Fraunhofer Executive Board is also providing nearly 600,000 euros in backing.

Employers can support the transformation to sustainable mobility by setting up the necessary infrastructures, for instance by converting their fleets to electric vehicles and providing a charging infrastructure for their employees’ private vehicles.



1

PRODUCTION AND SERVICES

Joseph von Fraunhofer Prize

Measuring ice hockey moves 1

How fast does the puck shoot across the ice? Did it go into the goal or not? Analyses and game evaluations are an integral part of sports broadcasts. Thomas von der Grün, Norbert Franke and Thomas Pellkofer, together with an approximately 20-member research team from the Fraunhofer Institute for Integrated Circuits IIS, have developed a positioning technology that is based on measuring the time-of-flight of radio signals and is geared specifically toward the dynamic processes in ice hockey. This technology makes it possible for the first time to conduct and display game analyses in real time. What is special about this is the high sampling rate: the system measures the position of the puck 2000 times per second, and it determines the position of the individual players 200 times per second.

To create this tracking system, the research team paired expertise in positioning system technology, signal processing and radio technology with the system's centerpiece, a specific microelectronically integrated circuit. It combines basic requirements such as robustness, speed and precision – despite, for example, strong interference from wireless systems such as those created by interacting players and tens of thousands of Wi-Fi users in the sports arenas. To achieve this, a microchip was integrated both in the players' shirts and in the puck, which even led to a redevelopment of the puck: the new one with the microchip can withstand speeds of up to 160 km/h and acceleration forces of up to 10,000 g. Specifications of this scope are otherwise only found in aerospace or in military systems. All of these challenges had to be overcome for the puck to be accepted for games in major sports arenas. The technology made its public debut at the 2019 Honda NHL All-Star Weekend ice hockey games in San Jose, USA, in January 2019.



Joseph von Fraunhofer Prize

Film as a new experience – lifelike people in virtual worlds 2

Walk-in films, games, training courses and even modern medical assistance systems: virtual and mixed reality are gaining ground and enabling users to completely immerse themselves in their scenes. While it is already possible to render environments very realistically, people in these kinds of VR worlds often still appear artificial, and their movements unnatural. Those who can produce dynamic 3D models of humans and embed them in other scenarios hold one of the keys to this future market.

Ingo Feldmann, Dr. Oliver Schreer and Peter Kauff from the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI have found it. They were helped in this endeavor by their many years of expertise, for instance in 3D reconstructions for video conference systems. Their work goes beyond the patented 3D Human Body Reconstruction (3D HBR) software; they developed an entire production infrastructure with a recording studio. The software, for example, had to be designed to facilitate recording and processing of up to 1.6 terabytes of data per minute. The studio is equipped with 32 high-resolution cameras arranged as 16 stereo systems in a nearly four-meter-high light rotunda. A new lighting concept was also created that allows the individual to be uniformly illuminated from all sides, as well as be perfectly cropped from the background.

The first commercial volumetric video studio on the European mainland was established in the fx.center on the Studio Babelsberg grounds in 2018. To make that happen, the production company Volucap GmbH was founded jointly with Studio Babelsberg, ARRI, Interlake and UFA. At this studio, people and objects can be scanned three-dimensionally and transferred as holograms into virtual environments, where they can be viewed from all sides just like computer-generated 3D models.

Joseph von Fraunhofer Prize

Less is more – saving energy in chemical manufacturing

The chemical industry is one of the main pillars of the European economy and an international market leader. However, the energy-intensive processes required to produce feedstocks for such products as plastics, detergents and fertilizers account for around one-fifth of Europe's industrial energy consumption. In addition, energy is expensive – particularly in Germany.

When changing manufacturing processes, it must be ensured that quality standards are observed. Measurement data from system sensors, coupled with the computer memory and capacities that are now available at low cost, pave the way for developing reliable computational models of processes. Machine-learning methods aid in incorporating expert knowledge based on operating data to develop models for consistent product quality. This is the approach the team working with Dr. Michael Bortz and Prof. Karl-Heinz Küfer from the Fraunhofer Institute for Industrial Mathematics ITWM used to develop a model-based toolbox. It includes a hybrid model approach in which operating data is used when physical model representations are lacking. This approach forms the basis for a multicriteria optimization module, which has already resulted in double-digit percentage energy savings being achieved in an existing production system.

German chemicals company BASF SE and Swiss chemicals and pharmaceuticals company LONZA Group AG see enormous benefit in this. At BASF SE, the toolbox is available to hundreds of process engineers, representing disruptive progress for them – and it has applications beyond the chemical industry: it offers advantages anywhere there is a need to control processes with a large number of parameters.



Safe food 1

A mobile food scanner can determine whether food items are authentic and whether they have gone bad. The pocket-sized demonstrator unit measures the freshness of food, whether packaged or unpackaged. The core of the mobile scanner is a near-infrared sensor. In addition to determining the degree of ripeness of fresh foodstuffs, or the content of processed foods, it can also identify the provenance of products such as olive oil and salmon. This is how it works: consumers or food industry employees hold the scanner directly up to the surface of the food or its packaging film, and infrared light strikes the product. The device captures the light reflection pattern. Using machine-learning methods, the scanner was trained to be able to classify, based on the spectrum of reflected light, a product's firmness and thus its degree of freshness as well as its authenticity. Tomatoes and meat were the first products used for training.

The scanner sensor is made from off-the-shelf components, so it is relatively inexpensive. Apart from the scanner, the prototype also features an app and a cloud-based solution that lets users read and compare the measurements. The method is currently limited to homogeneous foodstuffs, but it could, in principle, also be applied in other contexts, to distinguish wood, textiles, plastics and minerals from one another. Participants in the project are the Fraunhofer Institutes for Optronics, System Technologies and Image Exploitation IOSB and for Process Engineering and Packaging IVV, Deggendorf Institute of Technology, Weihenstephan-Triesdorf University of Applied Sciences and the Bavarian State Ministry of Food, Agriculture and Forestry's Competence Center for Nutrition (KErn). The project is one of the Bavarian ministry's "We Rescue Food" funding initiatives.



Villages as digital ecosystems 2

The Digital Villages project is aimed at making rural life as attractive as life in smart cities. In summer 2015, three communities of an association of municipalities in Rhineland-Palatinate – Eisenberg, Göllheim and Betzdorf-Gebhardshain – serving as a living lab in the Smart Rural Areas research program launched a number of modern neighborhood assistance concepts. Since then, many other municipalities have joined the model project, whose modular structure enables the scope and design to be flexibly tailored to the needs of the municipality, or new services to be added. There are now nearly 100 “digital villages” spread throughout Germany. The digital ecosystems this creates combine traditional village life with modern technology.

The first initiatives were local supply services “BestellBar” and “LieferBar”; by late 2019, communication and administration options had been added. DorfFunk and DorfNews, for instance, provided avenues for local residents to communicate by radio and newspaper, while the “LösBar” provided a channel for communicating with local government, forwarding residents’ suggestions and problems to municipal administrations. These concepts and solutions, developed at the Fraunhofer Institute for Experimental Software Engineering IESE, show the opportunities a holistic approach to digitalization in rural areas offers. The consortium is made up of the Rhineland-Palatinate Ministry of Home Affairs and for Sports, Fraunhofer IESE, Entwicklungsagentur Rheinland-Pfalz e.V. and the municipalities Betzdorf-Gebhardshain, Eisenberg and Göllheim.

Sustainability and quality in the foundry

Light metal foundry Leichtmetallgießerei Bad Langensalza succeeded in reducing its energy needs and CO₂ emissions. With modular, expandable burner technology and decentralized melt supply, companies can save as much as 60 percent of production-related energy costs and 80 percent of CO₂ emissions. A new burner system uses an efficient and extremely clean gas to produce the thermal energy needed for melting and holding, delivering control system performance and temperature homogeneity previously only seen in electrically heated units. For the first time, the waste heat produced is reliably recycled. This burner system is the centerpiece of an innovative process concept: the melting material is melted, transported and held at docking stations in mobile crucibles. This eliminates the dangerous, energy-intensive and quality-lowering emptying processes between the smelter, the transfer ladle and the holding furnace while at the same time significantly boosting the quality of the cast products and increasing production flexibility. An innovative sensor system continuously monitors the entire process, thus creating the prerequisite for future automated and decentralized process control.

Participating in the ETAL project funded by the Federal Ministry for Economic Affairs and Energy (BMWi) were the Fraunhofer Institute for Factory Operation and Automation IFF, Otto von Guericke University in Magdeburg, promeos GmbH and Leichtmetallgießerei Bad Langensalza GmbH. In September 2019, a prototype that is ready for use in mass production and that already offers sustainable and digitally connected operation was installed at Leichtmetallgießerei Bad Langensalza.



1

ENERGY AND RAW MATERIALS

Climate-friendly heat pump

With their low CO₂ emissions, heat pumps are a favorite among future heating technologies. Most of the heat pumps in use today still run largely on refrigerants containing environmentally harmful fluorinated greenhouse gases. An EU regulation (the “F-Gas Regulation”) stipulates that these gases must be reduced starting in 2020, but most of the alternatives developed to date are toxic or flammable, and stricter legal security requirements are making heating systems with heat pumps more expensive.

A high-performance brine-to-water heat pump from the Fraunhofer Institute for Solar Energy Systems ISE uses propane, a natural gas, as the refrigerant. The global warming potential of this gas is extremely low. In addition, the LC150 prototype requires only a quarter of the refrigerant needed for commercially available heat pumps, making it suitable for indoor use in residential buildings – with no additional safety precautions. With just 150 grams of propane, the LC150 pump delivers a heating power of around 8 kilowatts, which is estimated to be sufficient to heat a single-family home with average heating energy consumption. The researchers achieved a significant improvement by using asymmetrical plate heat exchangers for their innovative approach: due to their design, asymmetrical heat exchangers require less refrigerant. In addition, using less oil in the compressor also significantly lowered the amount of refrigerant required.

Fraunhofer ISE conducts research along the entire heat pump value chain – from materials to component and device development to quality assurance and monitoring in the field. The institute has an accredited test lab for heat pumps and chillers.



Recycled batteries for electric vehicles 2

Most electric vehicles are equipped with lithium-ion batteries, and to a great extent, European companies have to import them. In addition, increasing vehicle electrification will lead to a rapidly rising number of used batteries. It is hoped that efficient recycling will make it possible to keep the valuable components and materials in the recycling loop at the end of the battery life cycle. This is the aim of the research and industry partners collaborating on the AutoBatRec2020 (Automotive Battery Recycling 2020) project. This initiative is part of the European Institute for Innovation and Technology (EIT) Knowledge and Innovation Community “KIC RawMaterials,” which is being coordinated by the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS in Alzenau and Hanau. Besides further research partners and companies such as Samsung SDI Battery Systems and UMICORE, project participants also include the Fraunhofer Institutes for Manufacturing Engineering and Automation IPA and for Silicate Research ISC.

Its goal is to develop efficient process cycles for recycling traction batteries on a pilot scale – from collecting used batteries to disassembling them to separating the individual types of material. Innovative, automated disassembly, crushing and sorting technologies are one of their focus areas. The diversity of materials and designs used in battery systems, and the expected increase in the quantity such systems in the life cycle, pose great challenges. The new solutions for disassembly processes and recycling-compatible design are also aimed at eliminating the risks involved in disassembly as a result of handling high voltages and flammable and noxious components. The project partners assess the various methods in terms of cost-effectiveness and sustainability. Custom-combining and refining these methods creates an economically promising value creation cycle for the reuse of old electric-vehicle batteries.

Manufacturing batteries ecologically and economically 1

Currently, the major automakers usually outsource their battery cell production to Asia – in part because of the lower energy costs in the production process there. To enable economical and ecofriendly manufacture of next-generation battery cells in Germany, researchers at the Fraunhofer Institute for Material and Beam Technology IWS in Dresden have developed a new transfer method for dry coating.

It entails, first, mixing active material with binding polymers. Engineers then feed this mixture into a rolling mill to produce a flexible electrode film with high stability, which they laminate directly onto an aluminum foil. This creates a battery electrode that does without ecologically unsafe and energy-intensive wet chemical methods requiring pastes and subsequent drying processes, all of which necessitates complex industrial safety measures. In addition to conventional lithium-ion batteries, this innovative method can also be used for solid-state batteries with ion-conducting solids instead of flammable liquid electrolytes. It was not possible to treat the solid-ion conductors used in these batteries with the existing wet chemical method. The researchers are also using the new approach to process new electrode materials such as sulfur. These are precisely the kinds of materials that will be needed to manufacture future batteries with higher energy density. Finnish battery company BroadBit Batteries partnered with Fraunhofer IWS to open a pilot plant with a dry-coating process in May 2019. Now innovative sodium-ion batteries are being manufactured in Espoo, in the Helsinki metropolitan area. To further develop dry electrode coating on an industrial scale, additional companies are collaborating with Fraunhofer IWS on DryProTex, a funding initiative of Germany’s Federal Ministry of Education and Research (BMBF).



Hugo Geiger Prize

Resource-efficient corrosion-protection coatings 1

While completing his doctorate at the Fraunhofer Institute for Laser Technology ILT, Dr.-Ing. Hendrik Sändker developed innovative methods for manufacturing functional coatings from particulate polyether ether ketone (PEEK) using laser technology. A high-performance plastic, PEEK is more suitable than magnesium or other metals for coating metallic components if not only abrasion protection is required, but also high temperature and corrosion resistance. These kinds of specifications are needed in many industries – from mechanical and automotive engineering to generating plants for renewable energies.

Hendrik Sändker worked on various process steps; in addition to optics and laser technology – disciplines in which he is very much at home – he familiarized himself with polymer chemistry, metallic materials, simulation calculations based on thermodynamics, and the analysis and testing of functional coating properties. The physicist also participated in jointly funded initiatives with industry partners, making a significant contribution to developing tailored, laser-based manufacturing methods, for instance for temperature-sensitive metal components or for location-selective coating. This led to the first implementation of a dual-beam method with different laser beam wavelengths in this application field. Working with partners such as Schaeffler, Evonik, Mahle and ELB – Eloxalwerk Ludwigsburg, these methods will be transferred to industry. Leichtbau Baden-Württemberg, a state agency for the light-weight sector, presented ELB with the ThinkKing Community Award 2019 for the method it developed in collaboration with Fraunhofer ILT.

Environmental analytics with and for the public

Quickly and easily determining nitrate levels in the vegetable patch: that is what microelectronics experts at the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT, together with citizen scientists from the non-profit association FabLab München e.V., are working on in the Citizen Sensor project. Nitrates are essential to healthy plant growth, but in excess, they are harmful to the environment and pollute drinking water. However, obtaining truly meaningful measurements requires wide-ranging expertise and expensive laboratory equipment. The Citizen Sensor team's mobile lab is set to change that. It consists of an electrochemical measuring kit that delivers a direct value for the nitrate concentration in the soil and, with integrated digital step-by-step instructions, guides users through the process – from proper sample collection to evaluation of the results. Following initial field tests with some of Munich's urban gardening initiatives in summer, the project team has turned its focus to further optimizing the measurement process and making the device more robust. From the socioeconomic perspective, and with a view to wider utilization, the project is being supported by experts from the Fraunhofer Center for International Management and Knowledge Economy IMW and the Fraunhofer Information Center for Planning and Building IRB. Citizen Sensor is one of the 13 citizen science projects launched in 2017 with funding from the German Federal Ministry of Education and Research (BMBF). A total of five Fraunhofer consortia succeeded in securing such funding. In related studies, the researchers intend to determine where current utilization and cooperation models come up against their limits, and which aspects must be taken into account in the specific context of joint research with citizen scientists.



Using ceramic to obtain climate-friendly chemical feedstocks 2

Ceramics-based reactors and intelligently coupled power-to-X processes laid the foundation for a uniquely efficient laboratory facility in Dresden, which demonstrates how CO₂ can be produced from chemical feedstocks without impacting the climate. Several ceramic components and processes developed at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS were brought together to make this possible. First, CO₂, which occurs in large quantities and is unavoidable in, for instance, the cement and lime industry, is dedusted with filter candles and filtered through membranes. In a ceramic high-temperature electrolysis reactor, the carbon dioxide is converted to carbon monoxide at temperatures above 750°C. At the same time, hydrogen is produced from steam in the same reactor. Together, these two gases form the synthesis gas. This in turn is transformed into chemical precursors in a Fischer-Tropsch reactor, another component that was developed at Fraunhofer IKTS. Through closed and environmentally friendly material and energy cycles, the researchers strive to achieve an efficiency of more than 55 percent with the power-to-X system.

In another project in Saxony, Fraunhofer IKTS is collaborating with industry partners on a concept for using biogas to manufacture waxes. The plant is currently being built and readied for operation at the site in Thallwitz. Starting in 2020, cooperation partners will join in to scale up and expand the plant to include electrolysis. In a funding project dealing with structural change, a new modular plant concept is being created for the circular economy. This will be realized technologically by coupling biogas reforming and co-electrolysis in a high-

temperature electrolysis process. The concept is designed to allow the energy needed for the process to be obtained from both variable renewable energy and biogas. In addition to waxes, methane and synthetic oil for fuel production can also be manufactured in the new plant. Furthermore, by 2021, a partnership with a lime plant is slated to realize a facility that uses unavoidable CO₂ from the exhaust from lime production to produce synthetic waxes, for instance for lubricants.

AWARDS 2019



ERC Advanced Grant

A new breed of versatile and powerful fiber lasers

Prof. Jens Limpert, a physicist, and his research team at the Friedrich Schiller University in Jena have been awarded a prestigious ERC Advanced Grant. The European Research Council (ERC) has earmarked close to 2.5 million euros in funding over the next five years to support the team's efforts to build a high-performance fiber laser system. This project goes by the name of SALT, an acronym of sorts for High-Flux Synchrotron Alternatives Driven by Powerful Long-Wavelength Fiber Lasers. Its objective is to develop frequency-converted fiber lasers that generate coherent laser pulses in the infrared, terahertz and soft X-ray range, yet can be operated in standard laser laboratories. Limpert and his team in Jena aim to broaden the range of potential applications, which is currently limited to high-performance particle accelerators, or synchrotrons.

This Advanced Grant, one of the European Union's largest funding packages, is the third the ERC has awarded Limpert after a Starting Grant in 2009 and a Consolidator Grant in 2014. Prof. Limpert is the co-director of the Fraunhofer Cluster of Excellence Advanced Photon Sources CAPS.



ERC Starting Grant

Accelerating the transition to renewables to benefit the climate

Prof. Karoline Rogge, deputy head of the Competence Center Policy and Society at the Fraunhofer Institute for Systems and Innovation Research ISI, was awarded a Starting Grant from the European Research Council (ERC). Prof. Rogge and her research team at the University of Sussex are looking to accelerate the transition to more sustainable low-carbon energy and transport sectors in a project called EMPOCI (Governing sustainable energy-mobility transitions). Their analyses focus on Baden-Württemberg (Germany), California (USA), Guangdong (China), and Scotland (UK). These researchers aim to collaborate with businesses, government, scientists and societal stakeholders to develop transformative strategies and policies to promote climate-friendly innovations. The ERC is contributing 1.5 million euros to fund this project.

An economist and geo-ecologist, Rogge has been researching climate policy and innovation at Fraunhofer ISI since 2004. She is also professor of Sustainability Innovation & Policy and deputy head of the Sussex Energy Group at the Science Policy Research Unit (SPRU) of the University of Sussex, UK.



EARTO Innovation Award

Mathematical methods for radiotherapy

More than 20 years of research and applied science at the Fraunhofer Institute for Industrial Mathematics ITWM have culminated in an Innovation Award from the European Association of Research and Technology Organisations (EARTO). Fraunhofer ITWM earned this distinction in the Impact Delivered category for its interactive, easy-to-use software that supports decision-making and planning for intensity-modulated radiotherapy. Varian Medical Systems, the global market leader for radiation equipment, has licensed this software, which is to be deployed to more than 36,000 therapy planning stations around the world.

Developed by Prof. Karl-Heinz Küfer's research team, this efficiency-enhancing tool speeds up radiotherapy planning by as much as 80 percent. It helps physicians strike a good balance between the potential therapeutic benefits and possible side effects to improve the chances of recovery. The tool is based on multi-criteria optimization, a mathematical method of aligning different objectives. It can even serve to reconcile contradictory goals. Users report a 30 percent reduction of the radiation dose to organs at risk and improved tumor coverage.



EU Champions Challenge

Digital innovation hubs

Digital innovation hubs stepped up to compete for the first time at a European champions challenge in Madrid. Digital Hub Logistics took first place in two categories, SME Orientation and Service Portfolio.

The Dortmund-based innovation ecosystem for logistics is one of twelve hubs selected by the German government to drive the economy's digital transformation. It offers start-ups the space and infrastructure needed to develop digital products and business models. The Fraunhofer Institute for Material Flow and Logistics IML, the Fraunhofer Institute for Software and Systems Engineering ISST, EffizienzCluster Management GmbH and Duisburger Hafen AG support Digital Hub Logistics in Dortmund.



Thuringian Research Prize

A more ecofriendly ceramic battery

An R&D team at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS won the Thuringian Research Prize, taking top honors in the Applied Research category for a ceramic battery that provides an affordable, ecofriendly means of storing energy. Developed by Prof. Michael Stelzer, Dr. Roland Weidl, Dr. Matthias Schulz, Heidi Dohndorf, Lutz Kiesel, Martin Hofacker and Benjamin Schüssler, it is made entirely of non-critical, domestically sourced raw materials such as common salt, aluminum oxide and nickel. This stationary sodium/nickel-chloride battery is durable, systemically efficient, and safe enough for installation in residential buildings. Its core is a solid-state electrolyte – that is, a tube made of a special ceramic and sealed at one end.

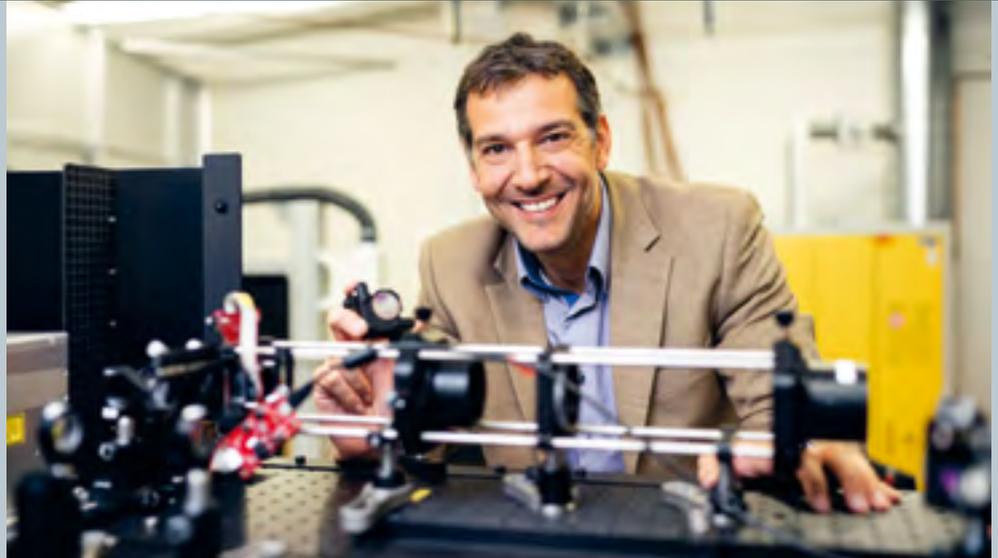
The research team developed the powders needed to make this battery and modified the sintering process. They also modeled a sophisticated corrosion-resistant ceramic seal to provide a permanent bond between the metallic cell wall and the ceramic core. But these experts' crowning achievement is their optimized cell design. This cell's storage capacity of around 250 watt-hours is nearly three times that of earlier stationary batteries of this type. A full-fledged battery module with 20 of these cells can store roughly the amount of energy collected by the solar panels of a single-family house on a sunny day.



Research grant from the Hans-und-Ruth-Giessen-Stiftung
Regenerative treatment of age-related eye disease

Dr. Ina Meiser, head of the Cryobiotechnology working group at the Fraunhofer Institute for Biomedical Engineering IBMT, has received a grant of 20,000 euros from the Hans-und-Ruth-Giessen-Stiftung for a project to investigate application-oriented cryopreservation for the regenerative treatment of age-related macular degeneration (AMD). One of the world's most common eye diseases, AMD is to blame for countless cases of blindness. A lifelong medication regimen can slow, but not stop, the disease's progression.

Meiser, a biologist, uses human-induced pluripotent stem cells in the laboratory to cultivate functional retinal cells that can serve to restore vision. She wants to safely store cell-based transplants for long periods to prevent the degradation of artificial tissue grown in the lab while it awaits transplantation in operating rooms. Clinical trials are already underway to evaluate her therapeutic approach. Meiser aims to use this award's endowment to fund a research stay at a partner institute in France that will further expand her network of partners for future collaboration.



**Argentinean national award
Excellence in engineering**

Prof. Andrés Lasagni, head of the Center for Advanced Micro Photonics at the Fraunhofer Institute for Material and Beam Technology IWS, and his twin brother Dr.-Ing. Fernando Lasagni, director at the Advanced Center for Aerospace Technologies (CATEC) in Seville, were honored with the Domingo Faustino Sarmiento award for their outstanding achievements in the engineering sciences. This prize is bestowed by the Senate of the Argentine Nation. The two engineers were born in Argentina. Andrés Lasagni is a leading international expert in laser technology with more than 250 scientific publications and over 30 patents to his credit. He and his team have succeeded in processing various materials with the direct laser interference patterning method, setting a world record with speeds of up to one square meter per minute.



Klaus Tschira Boost Fund

The building blocks of better hearing

Dr. Jan Rennies-Hochmuth, head of group at the Oldenburg branch of the Fraunhofer Institute for Digital Media Technology IDMT, has received a two-year grant from the Klaus Tschira Boost Fund. This affords Dr. Rennies-Hochmuth and his group the financial freedom and time to work on preliminary research projects with great potential for publication and to collaborate with scientists abroad. They want to better understand how speech is perceived in complex listening situations and explore how the brain connects the information picked up by each ear. The researchers aim to conduct speech intelligibility tests to gauge individual subjects' hearing and perceived listening effort, and then apply their findings to improve predictive models and applications such as hearing aids and communication systems.

VISIONS THAT WILL SHAPE TOMORROW'S WORLD

A contest of ideas

"To create sustainable value"

This year's contest of ideas at the Netzwert Symposium on February 18 and 19, 2020, was all about sustainable management. Over the course of these two days, 20 scientists presented their solutions to conserve resources, enable a circular economy, arrest climate change, ease the transition to renewables, and secure the water supply. The challenge was to pitch visionary yet ecofriendly and conservation-minded ideas that would create value and keep Germany and Europe competitive. Six winning teams – three on each day – received up to 5000 euros personal prize money and 25,000 euros in start-up financing.

Leatherwear made of mushrooms

Clothing, plastic and furniture fabricated with fungi? With mushrooms and organic waste such as sawdust, waste wood or fruit peels providing a sustainable alternative source of materials, fungus could indeed figure prominently in our future. Dr. Hannes Hinneburg from the Fraunhofer Institute for Applied Polymer Research IAP is pursuing this vision with his idea for a mushroom-based faux leather. "Fungi grow fast in just two to three weeks and require little water, energy and room, so they are a cost-effective and ecological alternative to cowhide," says the young scientist. Hinneburg now aims to apply tanning methods to toughen up and waterproof the mycelium's web-like structure, which is colored with dyes and shaped organically as it grows. A prototype is to be ready sometime in the next six months.

Going plastic-free in the garden

Germany churns through a lot of plant pots made of petroleum-based plastic – some three billion a year, most of which are disposable. Franziska Saft from the Fraunhofer Institute for Ceramic Technologies and Systems IKTS is eager to replace these synthetic pots, which are used on a massive scale in agriculture, with biobased alternatives. Made entirely of waste fibers, these new products are to be fully biodegradable. Researchers have now developed a technology to recondition waste fibers. This way, they can be put to productive use as feedstock for new products rather than going to waste in storage and disposal facilities.

Scaling up solar power for more biomass

Robert Schreiber from Fraunhofer headquarters and Felix Derwenskus from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB are determined to produce more algae in a much smaller space to increase the yield of biofuel production, for example. Their idea is to focus solar energy with a light guide and direct it to places where the sun does not normally shine, for example, in the basements of office buildings. According to the two researchers' calculations, this will increase per unit area productivity to 20 times that of conventional photobioreactors. The first step of their plan is to build a demonstrator that produces around ten liters of biomass at a go, while winning over internal and external partners to their project.



Energy fishing at the equator

If Jan Mohring has his way, thousands of solar pontoons will one day drift the ocean between Western Europe and the equator. Once they soak up enough intense sunlight to synthesize fuel from CO₂ and water, they will ride the Gulf Stream's current to return home. That is still but a vision, but Mohring, a mathematician at the Fraunhofer Institute for Industrial Mathematics ITWM, believes it would have a tremendous impact in weaning Western Europe off its dependency on global energy markets. Of course, it would also take a huge effort on all parts to realize this vision. For one, stakeholders would have to organize pontoons, synthesis plants and ships for transport to ports. "We can only make this venture happen if we get strong partners on board," says Mohring. He has the likes of Lufthansa and the German Federal Defence Forces in mind. Mohring also wants an internal consortium of Fraunhofer Institutes that specialize in energy and process engineering to help with the planning and provide scientific support.

Tracing products' sustainability credentials

Would consumers buy a washing machine if they knew that children were employed to make it? Of course not, but they are likely to have bought merchandise without being aware that child labor is part of its provenance. There is much we don't know about the products we buy. What resources were consumed in its manufacture? Under what conditions were its metals mined? Estelle Gervais and Shivenes Shammugam from the Fraunhofer Institute for Solar Energy Systems ISE have set themselves a lofty goal: They want to document information all along the value chain about material consumption, manufacturing practices and products' place of origin in a digital

format, and then protect this data with blockchain technology. The benefits of this sort of system would be many: Consumers win because they can make informed decisions about buying sustainable merchandise. Legislators can use it to set sustainability standards. And industries will have full traceability of their products. The two researchers now want to team up with other Fraunhofer Institutes to develop the system further, starting with photovoltaic modules.

Ecofriendly flame retardants

Some plastic products pose risks, as disasters like the 2017 fire that engulfed a London high-rise apartment building go to show. They can be treated to reduce the fire hazard, but many flame retardants contain halogens and antimony, which are harmful to human health and the environment. Flame retardants based on phosphorus compounds are a good alternative, but most are not organic or made in an ecofriendly way. Dr. Michael Ciesielski of the Fraunhofer Institute for Structural Durability and System Reliability LBF wants to change that. He has invented biobased phosphorous-based flame retardants that are harmless, yet highly efficient. Ciesielski's idea was to use cellulose, a phosphorus compound and sugar alcohols, which sell for very low prices these days, to produce a new breed of macromolecular flame retardant. This Fraunhofer LBF researcher has already achieved remarkable results with the process he invented. It not only lives up to all his expectations for sustainability and efficiency; it also produces cellulose acrylate intermediates suitable for use in paints and other coatings. Ciesielski aims to continue refining the new flame retardants and cellulose acrylates into industrial products in the hopes of seeing a lot more biobased compounds used in plastics.

PEOPLE IN RESEARCH

Enthusiasm and expertise are the lifeblood of our success. Here we turn the spotlight on seven researchers – from among the many like them who do such excellent work at our organization – to represent the face of Fraunhofer.



PROF. DR. PHIL. NAT. DR. MED. HABIL. ULRIKE KÖHL

Biologist and M.D. | Director of the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig | Professor and Director of the Institute for Clinical Immunology at the University of Leipzig | Director of the Institute of Cellular Therapeutics at the Hannover Medical School

Ulrike Köhl has devoted much of her life to fighting cancer. Her brother had suffered from the disease as a child, steeling her resolve to make a difference. This experience remains the driving force behind Köhl's determination to advance the cause of European cancer research.

After interning at hospitals, she set out to study biology with a focus on pharmacology. Köhl then went on to major in medicine, a combination that made a lot of sense to her. Pursuing a second degree was no easy undertaking for a young woman with two small children and a part-time job, but her ambition paid off. A postdoctoral scholarship from the Mildred Scheel Foundation took her to the MD Anderson Cancer Center in Houston for a year in 1995, where she delved deeply into cell and gene therapeutics. Oncology and immunology have been the focus of her work ever since. Today, she is a full professor who also heads the Fraunhofer Institute for Cell Therapy and Immunology IZI in Leipzig as well as two institutes at the University of Leipzig and the Hannover Medical School (MHH). A passionate researcher, her pet project at Fraunhofer IZI is investigating living cancer drugs. She had begun exploring this topic at the MHH and stepped up her research efforts later at Leipzig. "Our immune system protects us against disease, but bodily immune cells are sometimes too weak to fight cancer cells," says Köhl, an expert on the subject. "In CAR-T cell therapy, we take immune cells from patients and reprogram them genetically so they form a new receptor on the surface. They dock onto the

cancer cell like a key fitting into a lock, and then go on to destroy it." So far, this method has proven very successful in treating two types of blood cancer. Now Köhl and the researchers at her institute are striving to make this therapy work for other highly aggressive tumors.

One obstacle impedes this gene therapy – much of the production requires manual labor, which is costly. Eager to help more people, this physician wants to automate production and make it more flexible. That is no trivial matter given the complexities of personalized medicine. Clearly undeterred, Köhl says, "The Fraunhofer network has expertise in AI, robotics, life sciences and IT security and close ties to industry. It is better suited than any other organization for setting up modular production processes for CAR-T cells along Industrie 4.0 lines – with all the quality control, safety and documentation that that entails. It means so much to me to be able to start this up in a joint effort with other Fraunhofer Institutes and outside partners such as pharmaceutical companies." A talented networker, Köhl certainly values the benefits of collaboration. Another top priority for her is to build and expand a European network for cell and gene therapy.

Her heavy workload leaves this researcher with little free time. An avid cyclist, she takes her daily commute to work and between her institutes as an opportunity to pursue her passion. "It clears my mind."

PROF. DR. SCI. RAOUL KLINGNER

Holder of a B. Sc. in wood science and technology | Director of Research Management and Governance, Fraunhofer-Gesellschaft, Munich

Intrepid, inventive and empathetic – Raoul Klingner had to check all those boxes when he began work on a doctoral thesis in a lab he shared with hornets. As a postgrad student, he set out to investigate how these creatures perfected climate control in their nests, which happen to be masterpieces in lightweight wood design. Those same qualities work in his favor in his current position as Director of Research Management and Governance at the Fraunhofer-Gesellschaft. “In my job, it is important to have the courage to explore new avenues. I have to quickly acquaint myself with diverse subject matter, spot the sticking points, and figure out what motivates the various players,” says Klingner.

One of his many varied tasks is to keep on top of what each of the 74 Fraunhofer Institutes is doing; another is to follow important developments in business and politics. He prefers to do this face to face whenever he can, which is why he spends so much time on the road. „This is the only way to provide the competent support the institutes need to pursue their scientific mission and to coordinate the collaboration among them.” He wants to bring down the barriers that sometimes impede this cooperation. “If we work together effectively, we can fully exploit our potential through our broad range of services,” says Klingner with conviction. He should know, being an “old hand in the business,” as he puts it with a wink. Klingner has been with Fraunhofer for 15 years, initially joining the Strategic Planning and Research Programs department and later moving on to head up International Business Development before taking on his current position.

Klingner was born and raised in the Upper Bavarian town of Weilheim. His fascination with science and politics dates back to his school days. Setting out with a scholarship from the international exchange program sponsored by the German federal parliament, he attended high school in North Carolina for a year. “That’s where I learned to adapt to other cultures, expectations and situations. This benefited me later when working in an intercultural setting.” After graduating from the University of Hamburg, Klingner went on to earn a doctorate from the Empa Institute in Zurich, the part of the Swiss Federal Institute of Technology (ETH) that specializes in application-oriented materials research. “A restructuring was underway at the institute when I completed my doctorate there. Fraunhofer was held up as an example well worth emulating – that caught my attention.” After completing his dissertation in fall of 2005, he jumped at the opportunity to join Fraunhofer headquarters as a research fellow in the Research Management department. “It was the right place for me to help improve the general conditions for research, which was a prospect that appealed to me.”

Three years ago, he started sharing his wealth of experience in science and innovation management with students at TU Braunschweig. He certainly has plenty of real-world examples to impart his knowledge and methods. “I really enjoy working with the students; it’s inspiring and challenging. I learn a lot by doing this.” Klingner was appointed honorary professor in November 2019. He has no regrets about being out of the lab. “There’s so much research going on around me that I don’t miss anything. I’m very aware of my responsibility in everything I do. Fortunately, a great team supports me in my efforts. I have the best job imaginable!”





MARTA GILABERTE BASSET

Doctoral student | Member of the Quantum Imaging group at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena | M. Sc. in Aerospace Science and Technology; B. Sc. in Physics

“Opportunities are born of staying open to new ideas and entertaining all the possibilities that crop up along your chosen path,” says Marta Gilaberte Basset. This adage has proven most beneficial to the young physicist and aerospace researcher in her chosen field of research, quantum imaging. The same can be said of her career to date.

When opportunity knocked in 2018, she opened the door, relocating to Jena to work on her doctoral research with erst-while project partners. This also brought her into contact with the Fraunhofer Institute for Applied Optics and Precision Engineering IOF. A historic university town with a rich heritage in optics research and industry, Jena is surrounded by beautiful scenery dominated by impressive forests. Marta Gilaberte Basset loves that her current home is just a hop, skip and jump away from the countryside.

She does miss the ocean, though. A native Catalan, she left the ICFO – Institute of Photonic Sciences in Castelldefels, a seaside town with a beach on the Balearic Sea, to come to Jena. At the time, she also worked for the laser manufacturer Monocrom in nearby Barcelona, where she headed the development project for a Raman spectrograph. It was to set off on a very long journey in 2020. Developed by Marta Gilaberte Basset and her current colleagues at Fraunhofer IOF, this robust miniaturized spectrometer will be on board the European Space Agency’s (ESA) ExoMars mission to analyze the surface of the red planet.

A far cry from the great expanse of space, her current research focuses on the minuscule dimensions of the quantum world. She aims to harness the power of quantum entanglement for purposes of medical imaging in cancer diagnostics. The theory behind this application was developed by a team from Fraunhofer IOF and scientists at the prestigious Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences. The idea is to split a laser beam into twin entangled beams. One is directed at the sample while its twin serves to generate an image of that sample without ever having been directed at it. If this works, medical staff will be able to look at tissue at high resolution for extended periods. That is not possible today because conventional imaging causes such excessive damage to cells. Marta Gilaberte Basset built her first experimental setup for this sort of quantum source and demonstrated it at the 2019 LASER World of PHOTONICS.

“Magical” and “fascinating” are two words she uses to describe the quantum world. “We can’t really grasp it with our current understanding of mathematics and physics,” she says. “But we can see that it works in the lab! Ultimately, it’s all about allowing the existence of two different entities.”

This duality could also describe the road that Marta Gilaberte Basset has chosen for her career in science. After all, she is determined to see the fruits of her research widely applied in the real world. She hopes to soon provide medical engineering companies with quantum-based technology that delivers high-quality diagnostic images. “There’s something very satisfying about being able to accompany an invention from a concept to a prototype and out onto the market,” says Marta Gilaberte Basset.



PROF. DR. RER. NAT. MICHAEL STELTER

Electrochemist | Deputy director of the Fraunhofer Institute for Ceramic Technologies and Systems IKTS at Hermsdorf and Dresden | Professor for Technical Environmental Chemistry

Michael Stelter likes to see things in context. A native-born Saxon, Stelter first majored in physical chemistry and electrochemistry, and then branched out to study technology impact research, a field related to technology assessment. "It's very important to me to be able to explain the benefits of our research to people," says the energetic 46-year-old scientist. It is clearly no coincidence that his research focuses on resource-sparing energy storage systems and processes.

Stelter has worked at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS since 2005, heading the Modules and Systems department until 2010 and the Processes and Components research field from 2010 to 2013. Taking on the mantle of deputy director in 2013, he has been helping to manage this central German materials research institute and making decisions about the development of high-performance ceramic materials and industrial manufacturing processes ever since. He also teaches at the University of Jena, where he is professor of Technical Environmental Chemistry. His focus in this branch of science is on developing novel physical-chemical processes for water purification. As a researcher, he wants to develop technologies that treat water as a vital resource.

"I hadn't intended to go into research after finishing my studies," says Stelter, a father of two. He adds that he was unimpressed with the German university system in the 1990s after the fall of the Berlin Wall. Instead, the newly qualified chemist embarked on a career in the automotive industry, where he held various management positions. He headed the Fuel Cell Development work group at Webasto AG in Munich

from 2002 to 2005, where he built a fuel cell that he had started optimizing in the course of research conducted during his university days. It was then that Stelter first touched bases with Fraunhofer IKTS, seeking to jointly develop a ceramic fuel cell, which was an unprecedented approach at the time. This venture culminated in a spin-off from Webasto. Stelter, its designated CTO, was instead recruited by the director of Fraunhofer IKTS and appointed head of department to set up a unit to develop fuel cells. "IKTS was keen to develop complete systems rather than just work with individual materials. That appealed to me."

His intensive research culminated in an award in April 2019. Stelter and fellow researchers at Fraunhofer IKTS garnered the Thuringian Research Prize for a ceramic battery made entirely of non-critical, domestically sourced raw materials such as common salt, aluminum oxide and nickel. A ceramic battery from the institute has been gracing the Energy and Environment exhibition in Munich's Deutsches Museum since November. "The ceramic battery is a serious alternative to the lithium-ion battery in the context of the exit from fossil fuels, which demands storage possibilities for alternative energy sources," says the researcher.

Speaking of this topic – the transition to a sustainable energy system – Stelter says he is happy to be working in research: "Fortunately, science is ruled by factual evidence and laws of physics. We're not going to budge on that, not even by a millimeter. We develop practical solutions that work and create jobs."

DR. PHIL. KATHARINA WÄSCHLE

Computer scientist | Research fellow with the Mobile Terrestrial Scanning group at the Fraunhofer Institute for Physical Measurement Techniques IPM in Freiburg

“We can work our way to a slice of knowledge with every research project. But that doesn’t lessen the awe with which we contemplate the world’s complexity.” An outlook very much rooted in scientific curiosity, it inspired Katharina Wäschle, a computational linguist and computer scientist, to remain true to the world of science after earning a master’s degree with distinction. Keen to investigate machine learning, she looked into ways of improving machine translations in her doctoral thesis. In 2019, the young researcher and two colleagues garnered the Joseph von Fraunhofer Prize for their efforts. Working at the Fraunhofer Institute for Physical Measurement Techniques IPM, this team developed a smart data interpretation tool for Deutsche Telekom. It is part of a novel process chain that uses machine learning methods to speed up engineers’ efforts to map out routes when laying fiber-optic cables.

Wäschle wants to dispel people’s reservations about machine learning while pointing out that this innovative technology has its limits. She says, “Attempts to anthropomorphize AI and the notion of a magical tool that will solve every problem are misguided, realistically speaking,” adding that accuracy in describing problems and looking at what and how these systems actually learn is the key to achieving good results. “We shouldn’t impose our assumptions on the system and overestimate what it can do. It helps to be aware of what a narrow slice of the world a machine-trained system can actually see,” she says, speaking her mind as an expert.

The award-winning project for Deutsche Telekom provides a good example of how these systems are trained. Sidewalks and streetlights look different from region to region. “So we established a process to spot these differences. We set up a platform where we could enter the places in Germany where the appearance of sidewalks, tram lines and urban centers is known to vary from the purported norm. We used this as the baseline for putting together routes to record as many variations as possible. That worked very well. We were able to increase the recognition rate from 10 to 80 percent for some street scenarios.”

Wäschle joined Fraunhofer IPM for the route-planning project. She had no trouble making the transition from speech to image recognition. The very diverse team at Fraunhofer IPM also made it very easy for her to fit in. “The people who work here have a wide range of interests and think outside the box,” says Wäschle, who has two daughters. The move to Fraunhofer put her in touch with application-oriented research: “It’s so motivating when a research project yields a tangible benefit.” When working with a customer as a project manager, she prefers to use reliable, established methods that users can readily handle – even if these are not always the very latest in research tools. “I have to save the icing on the cake for the best model, which goes on my postdoc page,” says the researcher. She has certainly found her place at Fraunhofer – and dispensed with the notion that a researcher cannot serve the interests of both science and industry.





PRIV.-DOZ. DR.-ING. OLIVER SCHREER

Engineer | Associate professor at the Technical University Berlin | Head of the Immersive Media & Communication group at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI in Berlin

Turning a passion into a profession can be a wish come true for some. Oliver Schreer is one of those people. Born in Munich, he has been fascinated by moving images ever since his childhood. Now has been researching in this field for nearly 30 years. As a research fellow at the TU Berlin, he investigated ways of using stereo cameras to help mobile robots navigate on their own. When Schreer joined the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI in 1998, he could not have found an employer better suited to his interests. "Fraunhofer HHI conducts cutting-edge research, time and again developing prototypes with capabilities no one else has been able to realize."

An EU initiative called VIRTUE was his first major project at Fraunhofer HHI. Running from 2000 to 2003, it was also the first time the electrical engineer looked into 3D video communication. The premise for this project was for several cameras to film a person in front of a display. Algorithms would then adjust the viewing angle in real time so the person on camera looks the viewer straight in the eye. It was then that Schreer found his specialty field, 3D video analysis. Another milestone was RUSHES, a European FP6 project that ran from 2007 to 2009. The first EU project he headed as coordinator, it yielded an annotation tool for image and video search engines. "This major foundational research project with twelve partners was a success. I am very proud of that," says the researcher. Schreer has pursued other projects centered on new technologies such as real-time 3D video processing, gesture analysis, human-machine interaction and immersive media appli-

cations for augmented and virtual reality. He has also been teaching stereo analysis and view synthesis to students at TU Berlin since 2001.

The 2019 Joseph von Fraunhofer Prize came as a career highlight. Schreer and his colleagues Ingo Feldmann and Peter Kauff received the award for their work on 3D human body reconstruction (3D HBR). This technology would provide the means to set up a volumetric video studio in Potsdam-Babelsberg. Its 32 cameras capture the motions of people from all sides. These images are then integrated into virtual environments as lifelike 3D holographic avatars. "This is a prime example of application-oriented research achieving commercial success, which is what every researcher strives for," says the scientist. He can foresee this technology benefiting society in other applications, for example, in medicine. "If we manage to capture surgical procedures volumetrically, surgeons could be trained in the virtual realm and live animal models would no longer be needed."

The scientist has since turned his attention to two lofty visions. "I want to make it possible for a blind person and a deaf-mute person to communicate with each other in 3D." He is also keenly interested in preserving humankind's cultural heritage. A joint project with the film production company UFA is a case in point: A three-dimensional volumetric video of Jewish Holocaust survivor Ernst Grube captured his story for posterity. "It's very important to me that my work benefits society," says Schreer.

PROF. DR. MED. DR. RER. NAT. DR. MED. HABIL. GERD GEISSLINGER

M.D., licensed physician and pharmacist, specialist in clinical pharmacology | Executive director of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and Director of the Department of Clinical Pharmacology at the Goethe University in Frankfurt am Main

Mathematics, physics, chemistry and biology were Gerd Geißlinger's favorite subjects at school. These interests prompted him to major in pharmacy. "This course of study is very well suited for learning the fundamentals of pharmaceutical research and seeing how key concepts are connected. But a grasp of the pathophysiological mechanisms and knowledge of disease pathologies still evaded me. That's why I embarked on a second course of study, majoring in medicine," says the researcher, who holds two doctorates. After earning post-doctoral lecturing qualifications in pharmacology and toxicology, Geißlinger thought he would pursue a career in the pharmaceutical industry. A six-month stint at St Vincent's Hospital in Sydney, Australia, prompted him to reconsider. The freedom of researching and teaching at a university held a greater attraction, so he changed his plans. Three universities offered him a professorship; Geißlinger opted for Frankfurt am Main.

"We had already set up an interdisciplinary center for drug research, development and safety in Frankfurt 20 years ago with the support of the Hessian state government and the company formerly known as Aventis. We wanted to join forces across institutes and clinics to work on projects along the value chain," says the researcher. When the question arose about the feasibility of turning this network into an institute, a partner in applied research seemed like the best choice. This is how Geißlinger arrived at Fraunhofer.

What he really likes about Fraunhofer is its transdisciplinary structures, which enable researchers to work with people in other fields such as engineers and computer scientists. He believes that collaborative formats like this are the key to success in translating cost-minded new ideas into applications. He and his team developed the concept of the 4Ds that calls for collaboration across the four areas of drugs, diagnostics, data and devices. As Fraunhofer's health research officer, he is also striving to develop models for in-house collaboration to better tap the organization's potential across disciplinary boundaries. "We want to shape medical advances to benefit patients and contribute to optimum healthcare with cutting-edge, transdisciplinary research. The goal is for Fraunhofer to become a high-profile global player in health research. We are in an excellent position to accomplish this, thanks to the transdisciplinary collaboration among the professionals behind the 4Ds – doctors, engineers, computer scientists and natural scientists," says Geißlinger.

He has many awards for his excellent research work to his credit, including the Leon Goldberg Award, the Sertürner Prize, the research prize of the German Association for Palliative Medicine (DGP) and an honorary award from the German Pain Association (DGS). He is also co-publisher and co-author of "Mutschler Arzneimittelwirkungen", a standard German reference work. In what little spare time he has, the father of two hikes and cycles to recharge his batteries.



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.

AMPEERS ENERGY GmbH

Digital business models centered on sector coupling

Sector coupling – that is, using technologies to interconnect the electrical power, heating and transport sectors – is vital to the transition to renewables. AMPEERS ENERGY GmbH, a Fraunhofer spin-off founded in May 2019, offers innovative software-as-a-service solutions for sector coupling to B2B customers. Its product range encompasses a power management system for an entire neighborhood, an app to manage the supply of locally generated electricity to tenants, and a software solution to control the charging of e-vehicles. This start-up is seeking to turn the transition to sustainable and decentralized energy supply into a profitable business model for companies.

“Having already won over our first customers, we are now working with them to make this happen,” says Dr. Karsten Schmidt, founder and managing director of the freshly minted start-up. Target groups include the housing sector, power companies and fleet operators. “Our solutions help these companies optimize their energy management and cut energy costs,” says Schmidt, a former staffer at Fraunhofer headquarters. These solutions are based on an AI-supported energy management platform developed by the Applied Systems Technology (AST) branch of the Fraunhofer Institute for Optonics, Systems Engineering and Image Exploitation IOSB.

“We are delighted to have found an innovative, experienced partner with a long-term outlook for our energy management software know-how. This enables both us and AMPEERS ENERGY GmbH to develop new markets and growth opportunities,” says Prof. Dr. Peter Bretschneider, head of the Energy department and deputy director of the branch of the institute.

Last June, the fledgling company was able to secure a seven-digit figure in seed funding. Its backers include the Fraunhofer-Gesellschaft and the Jost Group. This investment will also finance the company’s efforts to develop and roll out products. The medium-term goal is to develop and market technologies for cognitive energy systems that deliver power in a highly automated and reliable way across sectors.



Skinmade GmbH

A micro-factory for personalized cosmetics

A lotion tailored to suit the individual's skin condition? Surely this is the stuff of cosmetic researchers' and dermatologists' dreams. Researchers at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA teamed up with Dermatest to achieve a breakthrough on that front. The spin-off Skinmade has built a micro factory that produces a personalized skin-care cream in a matter of minutes. "Conventional skin-care products may contain too much of certain active ingredients for a given individual, and that can be detrimental to their skin," says Viktor Balzer, Skinmade founder and research fellow at Fraunhofer IPA. Skinmade takes a different approach, tailoring the ingredients and dosage to the individual's skin and its current condition. This produces a far more effective cream.

This concept's success is also down to its no-fuss skin analysis. A beauty counselor gauges skin properties on the forehead, cheek and below the corner of the mouth. One probe takes moisture readings while another device measures the oil content on the skin's surface. Each reading takes no more than 30 seconds. The results appear on the touch display. An automated routine determines the optimum care for the current skin condition based on this analysis. The customer can then decide whether they want a light or a heavy cream with or

without fragrance. Then the micro-factory starts dosing and homogenizing contaminant-free ingredients such as hyaluronic acid, aloe vera and sodium lactate. A few minutes later, the customer has a small jar of personal cream to take home. Thirty milliliters cost around 40 euros.

One micro-factory is already up and running in a Frankfurt outlet of the Douglas retail chain. The brand also has a store of its own in Berlin. Another 20 cosmetic studios have the tools for these skin analyses, the results of which they send to the factory in Stuttgart. It produces the cream on demand and then sends it straight to the customer. The company plans to roll out a full skincare system in 2020 with a problem solver, personalized serum and cleanser. Skinmade also wants to offer medical ointments, for example, for diabetics and people with neurodermatitis, at some point in the future.



PerioTrap Pharmaceuticals GmbH

A highly specific agent to combat periodontitis

Periodontitis is a very common disease. More than half of all adults in Germany suffer from this bacterially induced inflammation of the gums. There is no cure, and merely administering broad-spectrum antibiotics is not a viable solution. A research team at the Fraunhofer Institute for Cell Therapy and Immunology IZI and the Molecular Drug Biochemistry and Therapy Development (MWT) branch lab at Halle joined forces with scientists from the University of Krakow and the Berne Dental Clinic to develop and patent a highly specific active ingredient to treat periodontitis. PerioTrap Pharmaceuticals, a start-up launched in 2018, is striving to bring this new development to market. Researchers from Halle and the Fraunhofer-Gesellschaft have a stake in the company as its founders.

“The new active substance is doubly selective – that is, it is absorbed exclusively by and acts only on the germs that cause the disease. Administered locally in the periodontal pocket, it does not stress the organism. And it mitigates the development of resistances,” says Dr. Mirko Buchholz from Fraunhofer IZI, one of the two managing directors and founders of PerioTrap. An initial idea for a delivery system has been developed to optimize the drug’s effect: An absorbable rod as flexible as a thread releases the test agent over the course of 42 days, a very long period by any count. The state of Saxony-Anhalt supported this development effort by funding a project that saw the Fraunhofer High-Performance Center Chemical and Biosystems Technology join forces with the Fraunhofer Institute for Microstructure of Materials and Systems IMWS and the universities of Bern and Halle.

There is a long way to go yet before the agent is licensed and can be brought to market. First it has to undergo a preclinical trial, where it will be tested for toxicity and on living organisms. This preclinical phase will be followed by clinical trials to test the agent in studies with humans.

MonitorFish GmbH

Smart means of monitoring aquacultures

Less than perfect conditions for their stocks cost fish farms 40 percent of their potential earnings on average. Launched in January of 2019, MonitorFish has set out to put an end to those losses. Its core technology is an AI-based system to monitor the wellbeing of fish in aquacultures, which it developed in collaboration with the Fraunhofer Institute for Computer Graphics Research IGD. The system reviews data sourced from sensors and cameras to analyze growth indicators and recommend actions for specific species. “The fish yield can be doubled with our technology,” says CEO and co-founder Chaitanya Dhumasker.

The company aims to provide expertise to fish farms by recommending actions at the earliest opportunity. “We are faster than the fish experts,” says Dhumasker. This early warning system prevents a catastrophic loss of fish and mitigates farmers’ financial risk. Optimized amounts of feed and fertilizers also reduce environmental pollution.




The German Federal Ministry of Education and Research (BMBF) funded the MonitorFish team in 2018 as part of its TechBridge project. The team also received funding from the FTTF (Fraunhofer Technologie-Transfer Fonds) in 2019. The start-up came up with the camera technology; Fraunhofer developed the smart algorithm and granted the start-up a license for its underwater image recognition software. The company is now readying the system's rollout. Tests are underway with three pilot customers in Germany, Austria, and Switzerland to further improve the cameras and the algorithm. These tests have already yielded insights. For example, fish do not thrive under bright camera light, which is why the system has been modified to work with red light. The company expects its pilot customers to soon become bona fide customers when it ramps up for real business in May 2020.

Psoido GmbH

The ticket to anonymous pseudonyms

Many companies' success hinges on their ability to analyze business data in great detail. This often runs counter to data privacy concerns. Psoido GmbH has found a way out of that conundrum. Spun off from the Fraunhofer Institute for Digital Media Technology IDMT in late June 2019, this enterprise provides a software-as-a-service solution that severs the ties between real and virtual identities. This enables companies to conduct sophisticated data analyses without the source being traceable. In other words, Psoido enables owners to retain sovereignty over their data, yet share it easily and quickly.

"Psoido offers the only solution when a system requires authenticated data with the real identity being protected and unique IDs for data analysis," says CEO Steffen Holly. The General Data Protection Regulation (GDPR), which harmonized data privacy laws in all EU member states when it came into force in May 2018, gave Psoido GmbH's business model a big boost. "Companies now have to live up to their data protection obligations. That drives our business," says Holly.

A patent held by Fraunhofer IDMT provided the launch pad for this spin-off. Holly, at the time a business unit manager, saw the potential and prepared the spin-off with a helping hand from Fraunhofer Venture. "The programs of the Venture department afforded us the opportunity to try things out before we ventured into the market," says Holly. The most suitable partners were soon found in the logistics and mobility sectors. Psoido GmbH received start-up financing from the FTTF (Fraunhofer Technologie-Transfer Fonds). The company is now planning to branch the software solution out into new lines of business such as banking (finance and insurance).





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BALANCE SHEET AT DECEMBER 31, 2019

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

ASSETS	€	€	2019 €	2018 € (1000)
Current assets				
Cash and cash equivalents		91,339,513.30		162,500
Marketable securities		415,311,929.94		384,659
Accounts receivable and other current assets				
Trade receivables	216,125,455.38			222,741
Receivables from the federal and state governments relating to base funding	103,002,368.39			25,399
relating to project billing, including contract research	204,330,271.08			146,901
relating to pension and compensated absence provisions	80,601,000.00			72,324
	<u>387,933,639.47</u>			<u>244,624</u>
Accounts receivable from associated companies	116,378.21			13,132
Other current assets	<u>122,417,827.70</u>			<u>127,762</u>
		726,593,300.76		608,259
Inventories		75,545,547.78		61,922
Prepaid expenses and deferred charges		<u>80,941,290.43</u>		<u>92,208</u>
Total current assets			1,389,731,582.21	1,309,548
Intangible assets			50,145,374.68	55,310
Property, plant and equipment			2,250,260,805.70	2,060,104
Financial assets			<u>18,248,218.97</u>	<u>20,624</u>
Total assets			<u>3,708,385,981.56</u>	<u>3,445,586</u>
Trust assets			21,820,363.23	33,626

LIABILITIES AND EQUITY	€	€	2019 €	2018 € (1000)
Current liabilities				
Trade payables		110,589,737.50		109,552
Unappropriated grants from the federal and state governments relating to base funding	194,121,057.29			187,631
relating to project billing	<u>99,788,602.24</u>			<u>110,068</u>
		293,909,659.53		297,699
Accounts payable to associated companies		650,851.70		1,224
Other current liabilities		<u>35,578,922.28</u>		<u>6,384</u>
Total current liabilities			440,729,171.01	414,859
Deferred income			4,713,780.57	122
Provisions for pensions and similar obligations			9,101,000.00	9,224
Other provisions			187,408,458.78	164,347
Special reserves				
License-fee revenue reserve		415,508,285.76		384,908
Grants relating to non-current assets		2,305,946,247.30		2,120,977
Grants used to finance current assets		265,213,563.44		265,152
Present value of deferred income from patent deal		<u>64,409,844.51</u>		<u>69,486</u>
			3,051,077,941.01	2,840,523
Equity				
Capital of the non-profit organization				
Carried forward	15,287,367.41			15,233
Retained earnings	<u>52,387.78</u>			<u>54</u>
		15,339,755.19		15,287
Restricted reserve		<u>15,875.00</u>		<u>1,224</u>
Total equity			<u>15,355,630.19</u>	<u>16,511</u>
Total liabilities and equity			<u>3,708,385,981.56</u>	<u>3,445,586</u>
Trust liabilities			21,820,363.23	33,626

INCOME STATEMENT FOR THE FINANCIAL YEAR 2019

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

	€	€	2019 €	2018 € (1000)
Revenue from base funding				
Federal government		846,646,386.66		768,020
State governments		<u>157,684,290.51</u>		<u>123,336</u>
			1,004,330,677.17	891,356
Revenue from own activities				
Revenue from research and development activities				
Federal government: Project funding		594,856,665.44		526,780
Contracts		22,602,915.75		14,543
State governments: Project funding		183,247,347.23		161,994
Contracts		1,874,319.10		2,329
Business, industry and trade associations		724,416,768.22		691,861
Research funding organizations and other sources		<u>166,615,723.58</u>		<u>188,249</u>
		1,693,613,739.32		1,585,756
Other revenue		<u>6,528,275.43</u>		<u>5,446</u>
Total revenue			1,700,142,014.75	1,591,202
Increase in work in progress		8,884,447.53		29,127
Other internally constructed and capitalized assets		8,963,808.42		8,179
Other operating income		33,991,831.40		43,326
Income from equity investments		1,802,769.54		4,298
Other interest and similar income		<u>2,001,592.57</u>		<u>1,233</u>
			55,644,449.46	86,163
Total base funding and revenue from own activities			2,760,117,141.38	2,568,721
Change in special reserves				
License-fee revenue reserve		-30,600,000.00		-46,000
Grants relating to non-current assets		-189,589,101.13		-161,354
Grants used to finance current assets		<u>-61,590.43</u>		<u>-17,597</u>
			-220,250,691.56	-224,951
Total income available to cover expenditure			<u>2,539,866,449.82</u>	<u>2,343,770</u>

	€	€	2019 €	2018 € (1000)
Cost of materials		406,171,074.84		381,115
Personnel expenses		1,465,299,974.89		1,350,182
Amortization of intangible assets and depreciation of property, plant and equipment		288,293,263.71		282,978
Other operating expenses		372,523,114.87		324,312
Amortization of financial assets and current marketable securities		8,066,293.90		4,452
Interest and similar expenses		<u>668,190.32</u>		<u>675</u>
Total expenditure			<u>2,541,021,912.53</u>	<u>2,343,714</u>
Net income for the year			-1,155,462.71	56
Transfer from reserves			1,211,050.49	-
Transfer to reserves			<u>-3,200.00</u>	<u>-2</u>
Retained earnings			52,387.78	54
Allocation to capital of the non-profit organization			<u>-52,387.78</u>	<u>-54</u>
			<u>-</u>	<u>-</u>

RECONCILIATION BETWEEN INCOME STATEMENT AND PERFORMANCE STATEMENT (CASH-BASIS ACCOUNTING) 2019

Income/receipts	Performance statement €	Non-profit organization capital €	Reconciling items €	Income statement €
Income/receipts				
from base funding	996,053,877.17		8,276,800.00	1,004,330,677.17
from research and development activities	1,706,236,752.01		-12,623,012.69	1,693,613,739.32
from other sources	397,237.70		6,131,037.73	6,528,275.43
Increase in work in progress			8,884,447.53	8,884,447.53
Other internally constructed and capitalized assets	8,963,808.42			8,963,808.42
Other income	39,845,904.02	342,762.06	-2,392,472.57	37,796,193.51
Total income/receipts	2,751,497,579.32			
Change in special reserves				
License-fee revenue reserve			-30,600,000.00	-30,600,000.00
Grants relating to non-current assets				
Allocations to special reserves (capital expenditure)			-481,058,980.83	-481,058,980.83
Reversal of special reserves (depreciation)		12,464.92	291,457,414.78	291,469,879.70
Grants used to finance current assets	-61,590.43			-61,590.43
Change in grants receivable relating to pension and compensated absence provisions	8,276,800.00		-6,306,500.00	
Total business volume (cash basis)	2,759,712,788.89	<u>355,226.98</u>	<u>-220,201,566.05</u>	<u>2,539,866,449.82</u>

Expenditure/disbursements	Performance statement €	Non-profit organization capital €	Reconciling items €	Income statement €
Expenditure/disbursements				
Cost of materials	373,241,585.57	23,917.77	32,905,571.50	406,171,074.84
Personnel expenses	1,478,534,011.33	5,640.00	-13,239,676.44	1,465,299,974.89
Amortization of intangible assets and depreciation of property, plant and equipment		182,139.43	288,111,124.28	288,293,263.71
Other operating expenses	396,272,263.54	1,298,992.49	-16,313,656.94	381,257,599.09
Expenditure as per the income statement				2,541,021,912.53
Change in special reserves				
License-fee revenue reserve	30,600,000.00		-30,600,000.00	
Capital expenditure (current and major infrastructure)	481,064,928.45		-481,064,928.45	
Net income for the year		-1,155,462.71		-1,155,462.71
Total business volume (cash basis)	2,759,712,788.89	<u>355,226.98</u>	<u>-220,201,566.05</u>	<u>2,539,866,449.82</u>

PERFORMANCE STATEMENT FOR INDIVIDUAL FRAUNHOFER ENTITIES

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding ¹
		2019 € (1000)	2019 € (1000)	2019 € (1000)	2019 € (1000)
Fraunhofer ICT Group					
Algorithms and Scientific Computing SCAI	Sankt Augustin	12,346.2	612.5	9,323.5	3,635.2
Applied and Integrated Security AISEC	Garching	10,541.3	167.9	6,836.3	3,873.0
Applied Information Technology FIT	Sankt Augustin	21,117.6	601.3	15,717.1	6,001.8
Cognitive Systems IKS München	München	6,337.0	157.8	2,985.4	3,509.4
Communication, Information Processing and Ergonomics FKIE	Wachtberg	9,048.1	238.5	6,923.5	2,363.1
Computer Graphics Research IGD	Darmstadt, Rostock	16,352.3	858.9	10,128.0	7,083.1
Digital Media Technology IDMT	Ilmenau, Oldenburg	11,341.9	232.7	5,815.0	5,759.6
Experimental Software Engineering IESE	Kaiserslautern	14,531.3	504.6	11,876.3	3,159.6
Industrial Mathematics ITWM	Kaiserslautern	31,376.7	2,629.9	22,682.7	11,323.9
Intelligent Analysis and Information Systems IAIS	Sankt Augustin	24,353.9	865.3	19,973.9	5,245.3
Medical Image Computing MEVIS	Bremen	11,126.0	587.2	7,058.2	4,655.0
Open Communication Systems FOKUS	Berlin	32,041.0	964.7	24,944.2	8,061.5
Optronics, System Technologies and Image Exploitation IOSB	Karlsruhe, Ettlingen, Ilmenau, Lemgo	34,558.7	1,640.5	25,991.0	10,208.2
Secure Information Technology SIT	Darmstadt	8,012.5	420.7	6,568.9	1,864.2
Software and Systems Engineering ISST	Dortmund	5,517.6	119.9	4,458.6	1,179.0
Transportation and Infrastructure Systems IVI	Dresden	11,999.1	1,828.5	11,913.9	1,913.7
Central office – Fraunhofer ICT Group	Berlin	296.5	14.6	103.9	207.1
		<u>260,897.8</u>	<u>12,445.4</u>	<u>193,300.4</u>	<u>80,042.7</u>

1 Figures rounded on the basis of real values.

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding ¹
		2019 € (1000)	2019 € (1000)	2019 € (1000)	2019 € (1000)
Fraunhofer Group for Innovation Research – INNOVATION					
Center for International Management and Knowledge Economy IMW					
	Leipzig	8,086.2	564.1	5,265.7	3,384.6
Industrial Engineering IAO					
	Stuttgart	36,970.2	1,233.6	32,075.8	6,128.0
Information Center for Planning and Building IRB					
	Stuttgart	7,681.7	143.6	2,728.4	5,096.8
Systems and Innovation Research ISI					
	Karlsruhe	28,571.3	620.6	22,364.3	6,827.7
Technological Trend Analysis INT					
	Euskirchen	<u>2,714.6</u>	<u>16.7</u>	<u>1,873.7</u>	<u>857.6</u>
		<u>84,024.0</u>	<u>2,578.6</u>	<u>64,307.9</u>	<u>22,294.7</u>
Fraunhofer Group for Life Sciences					
Biomedical Engineering IBMT					
	Sulzbach, St. Ingbert	16,811.8	676.3	13,582.8	3,905.2
Cell Therapy and Immunology IZI					
	Leipzig, Potsdam-Golm	39,924.4	1,857.3	27,507.6	14,274.0
Interfacial Engineering and Biotechnology IGB					
	Stuttgart, Leuna	25,185.3	1,221.4	18,321.7	8,085.0
Marine Biotechnology and Cell Technology EMB					
	Lübeck	2,712.7	6.2	1,221.7	1,497.3
Molecular Biology and Applied Ecology IME					
	Aachen, Schmallenberg	41,800.2	2,761.1	32,457.9	12,103.4
Process Engineering and Packaging IVV					
	Freising, Dresden	23,885.1	1,259.7	19,720.0	5,424.8
Toxicology and Experimental Medicine ITEM					
	Hannover, Braunschweig, Regensburg	<u>32,473.6</u>	<u>3,673.2</u>	<u>23,357.2</u>	<u>12,789.6</u>
		<u>182,793.1</u>	<u>11,455.2</u>	<u>136,168.8</u>	<u>58,079.4</u>
Fraunhofer Group for Light & Surfaces					
Applied Optics and Precision Engineering IOF					
	Jena	36,096.2	6,788.3	32,993.6	9,891.0
Laser Technology ILT					
	Aachen	42,253.5	8,377.6	33,343.7	17,287.4
Material and Beam Technology IWS					
	Dresden	31,881.6	2,924.9	24,590.6	10,216.0
Organic Electronics, Electron Beam and Plasma Technology FEP					
	Dresden	24,032.4	1,025.3	17,335.2	7,722.4
Physical Measurement Techniques IPM					
	Freiburg	19,876.2	568.6	12,836.6	7,608.3
Surface Engineering and Thin Films IST					
	Braunschweig	<u>12,768.4</u>	<u>1,387.7</u>	<u>7,093.6</u>	<u>7,062.4</u>
		<u>166,908.3</u>	<u>21,072.4</u>	<u>128,193.2</u>	<u>59,787.4</u>

¹ Figures rounded on the basis of real values.

**Performance statement for
individual Fraunhofer entities**

Fraunhofer Institute/ Research Institution for		Expenses		Income	
		Operating expenses	Capital expenditure	From external sources	Base funding ¹
		2019	2019	2019	2019
		€ (1000)	€ (1000)	€ (1000)	€ (1000)
Fraunhofer Group for Microelectronics					
Applied Solid State Physics IAF	Freiburg	14,642.8	2,802.1	11,886.1	5,558.8
Electronic Nano Systems ENAS	Chemnitz	15,315.8	1,232.8	12,372.7	4,175.8
High Frequency Physics and Radar Techniques FHR	Wachtberg	15,154.1	1,004.8	12,828.6	3,330.2
Integrated Circuits IIS	Erlangen, Nürnberg, Dresden	174,098.7	6,957.8	140,054.1	41,002.3
Integrated Systems and Device Technology IISB	Erlangen	28,559.4	2,204.7	23,329.3	7,434.9
Microelectronic Circuits and Systems IMS	Duisburg	38,671.6	1,339.4	23,025.1	16,985.9
Microsystems and Solid State Technologies EMFT	München	15,376.7	741.5	10,996.7	5,121.5
Photonic Microsystems IPMS	Dresden	44,685.9	1,097.3	31,353.6	14,429.5
Reliability and Microintegration IZM	Berlin, Dresden	35,658.3	2,126.1	28,023.3	9,761.0
Silicon Technology ISIT	Itzehoe	25,578.5	1,466.6	17,309.5	9,735.6
Telecommunications, Heinrich-Hertz-Institut, HHI	Berlin, Goslar	57,265.7	5,154.5	48,329.5	14,090.7
Central office – Research Fab Microelectronics Germany (FMD)	Berlin	1,966.8	483.6	1,173.4	1,277.1
		<u>466,974.2</u>	<u>26,611.0</u>	<u>360,681.9</u>	<u>132,903.3</u>
Fraunhofer Group for Production					
Additive Manufacturing Technologies IAPT	Hamburg	8,937.4	787.1	6,163.5	3,561.0
Casting, Composite and Processing Technology IGCV	Augsburg, Garching	16,147.5	1,805.9	14,656.1	3,297.3
Environmental, Safety and Energy Technology UMSICHT	Oberhausen, Sulzbach-Rosenberg	45,205.5	4,236.2	39,968.4	9,473.3
Factory Operation and Automation IFF	Magdeburg	20,260.1	489.4	15,641.3	5,108.2
Large Structures in Production Engineering IGP	Rostock	9,575.9	268.4	7,226.1	2,618.2
Machine Tools and Forming Technology IWU	Chemnitz	45,477.2	3,500.5	33,789.0	15,188.8
Manufacturing Engineering and Automation IPA	Stuttgart	66,634.5	4,110.3	55,082.5	15,662.2
Material Flow and Logistics IML	Dortmund, Hamburg	33,136.6	1,468.0	26,338.5	8,266.1
Mechatronic Systems Design IEM	Paderborn	11,805.2	640.5	10,620.0	1,825.7
Production Systems and Design Technology IPK	Berlin	20,038.0	2,113.6	13,975.2	8,176.4
Production Technology IPT	Aachen	28,846.0	836.9	21,436.4	8,246.5
		<u>306,063.8</u>	<u>20,256.8</u>	<u>244,897.0</u>	<u>81,423.6</u>

1 Figures rounded on the basis of real values.

Fraunhofer Institute/ Research Institution for		Expenses Operating expenses	Capital expenditure	Income From external sources	Base funding ¹
		2019 € (1000)	2019 € (1000)	2019 € (1000)	2019 € (1000)
Fraunhofer Group for Materials and Components – MATERIALS					
Applied Polymer Research IAP	Potsdam-Golm	24,146.3	2,421.5	17,802.5	8,765.4
Building Physics IBP	Stuttgart, Holzkirchen	27,773.4	1,070.0	19,786.5	9,057.0
Ceramic Technologies and Systems IKTS	Dresden, Hermsdorf	58,204.3	6,115.9	48,469.4	15,850.8
Chemical Technology ICT, Polymer Engineering Department	Pfinztal, Karlsruhe	27,460.1	3,475.5	20,954.0	9,981.6
Energy Economics and Energy System Technology IEE	Kassel	26,871.7	1,205.9	22,869.8	5,207.7
Energy Infrastructures and Geothermal Systems IEG	Bochum	287.0	0.0	0.0	287.0
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	9,047.7	1,237.8	7,054.7	3,230.8
Manufacturing Technology and Advanced Materials IFAM	Bremen, Dresden, Stade	52,471.0	4,054.4	41,947.8	14,577.6
Mechanics of Materials IWM	Freiburg	21,742.8	1,040.1	15,247.1	7,535.8
Microengineering and Microsystems IMM	Mainz	11,383.2	1,306.8	4,620.7	8,069.3
Microstructure of Materials and Systems IMWS	Halle	24,071.1	3,447.6	20,200.9	7,317.8
Nondestructive Testing IZFP	Saarbrücken	14,309.1	629.1	9,315.2	5,622.9
Silicate Research ISC	Würzburg, Bronnbach, Garching, Bayreuth	33,474.3	1,037.7	21,266.1	13,245.9
Solar Energy Systems ISE	Freiburg, Halle	92,433.8	10,396.0	88,394.4	14,435.4
Structural Durability and System Reliability LBF	Darmstadt	28,919.8	2,907.9	19,627.9	12,199.8
Wind Energy Systems IWES	Bremerhaven, Kassel	28,390.7	10,183.1	34,812.5	3,761.3
Wood Research, Wilhelm-Klauditz-Institut, WKI	Braunschweig	<u>15,980.0</u>	<u>2,838.5</u>	<u>13,863.6</u>	<u>4,954.9</u>
		<u>496,966.2</u>	<u>53,367.9</u>	<u>406,233.1</u>	<u>144,101.0</u>

¹ Figures rounded on the basis of real values.

**Performance statement for
individual Fraunhofer entities**

Fraunhofer Institute/ Research Institution for	Expenses		Income		
	Operating expenses	Capital expenditure	From external sources	Base funding ¹	
	2019 € (1000)	2019 € (1000)	2019 € (1000)	2019 € (1000)	
Additional research funding²					
ATHENE – Computer Graphics Research IGD	Darmstadt	1,291.7	78.0	0.0	1,369.6
ATHENE – Secure Information Technology SIT	Darmstadt	9,212.8	1,345.3	0.0	10,558.1
Research Fab Battery Cells (FFB) – Production Technology IPT	Münster	2,093.2	0.0	2,093.2	0.0
Applied Solid State Physics IAF	Freiburg	16,769.3	3,876.4	11,275.0	9,370.7
Chemical Technology ICT, Department of Energetic Materials	Pfinztal	14,483.6	833.1	4,375.0	10,941.8
Communication, Information Processing and Ergonomics FKIE	Wachtberg	27,371.6	2,019.7	15,945.5	13,445.7
High Frequency Physics and Radar Techniques FHR	Wachtberg	18,236.2	2,310.1	8,935.6	11,610.6
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	16,792.5	6,989.1	13,138.6	10,643.0
Optronics, System Technologies and Image Exploitation IOSB, Ettlingen branch	Ettlingen	22,438.7	5,182.8	19,931.9	7,689.6
Technological Trend Analysis INT	Euskirchen	<u>7,496.6</u>	<u>456.0</u>	<u>3,334.7</u>	<u>4,617.9</u>
		<u>136,186.1</u>	<u>23,090.4</u>	<u>79,029.4</u>	<u>80,247.1</u>
Centrally managed entities					
Fraunhofer headquarters	München	39,625.9	2,509.1	5,526.9	36,608.1
Institute Center Birlinghoven	Sankt Augustin	549.8	46.9	56.4	540.3
Institute Center Stuttgart	Stuttgart	83.9	146.2	8.5	221.5
General overhead costs		137,574.8	2,059.2	9,531.4	130,102.6
Major infrastructure capital expenditure			<u>305,425.8</u>	<u>127,508.6</u>	<u>177,917.2</u>
		<u>177,834.4</u>	<u>310,187.3</u>	<u>142,631.9</u>	<u>345,389.8</u>
Performance statement		<u>2,278,647.9</u>	<u>481,064.9</u>	<u>1,755,443.7</u>	<u>1,004,269.1</u>
Total business volume (cash basis)		<u>2,759,712.8</u>			

1 Figures rounded on the basis of real values.

2 Not including contract research activities of the defense-related institutes, plus ATHENE and FFB.

EXCERPTS FROM THE NOTES TO THE FINANCIAL STATEMENTS 2019

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, 2019 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, additional research funding, and major infrastructure capital expenditure.

Annual financial statements of the Fraunhofer-Gesellschaft		Reconciliation with income statement format required by public funding authorities
	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

Presentation of annual accounts of the Fraunhofer-Gesellschaft

II. Recognition and measurement methods

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

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

Institute buildings on own and third-party land are depreciated as follows:

- Added before April 1985: at 2 percent
- Added between April 1, 1985 and December 31, 2000: at 4 percent
- Added after January 1, 2001: at 3 percent

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

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

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

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

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

Current marketable securities are recognized at cost.

Cash and cash equivalents are recognized at their nominal value.

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

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 2.71 percent was used in the calculation in accordance with Section 253 (2) of the German Commercial Code (HGB), along with the 2018 G Heubeck guideline tables.

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 2019, 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, 2019, the income statement for the financial year 2019 and the full notes to the 2019 financial statements and the management report 2019.

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, 2019, and the statement of profit and loss for the financial year from January 1, 2019 to December 31, 2019 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, 2019 to December 31, 2019.

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, 2019 and of its financial performance for the financial year from January 1, 2019 to December 31, 2019 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.

Convenience translation of the
German independent auditor's report

**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 23, 2020

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

FURTHER INITIATIVES AND RESEARCH
INFRASTRUCTURES

ADDRESSES IN GERMANY

INTERNATIONAL ADDRESSES

EDITORIAL NOTES

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 **74 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 seven **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.

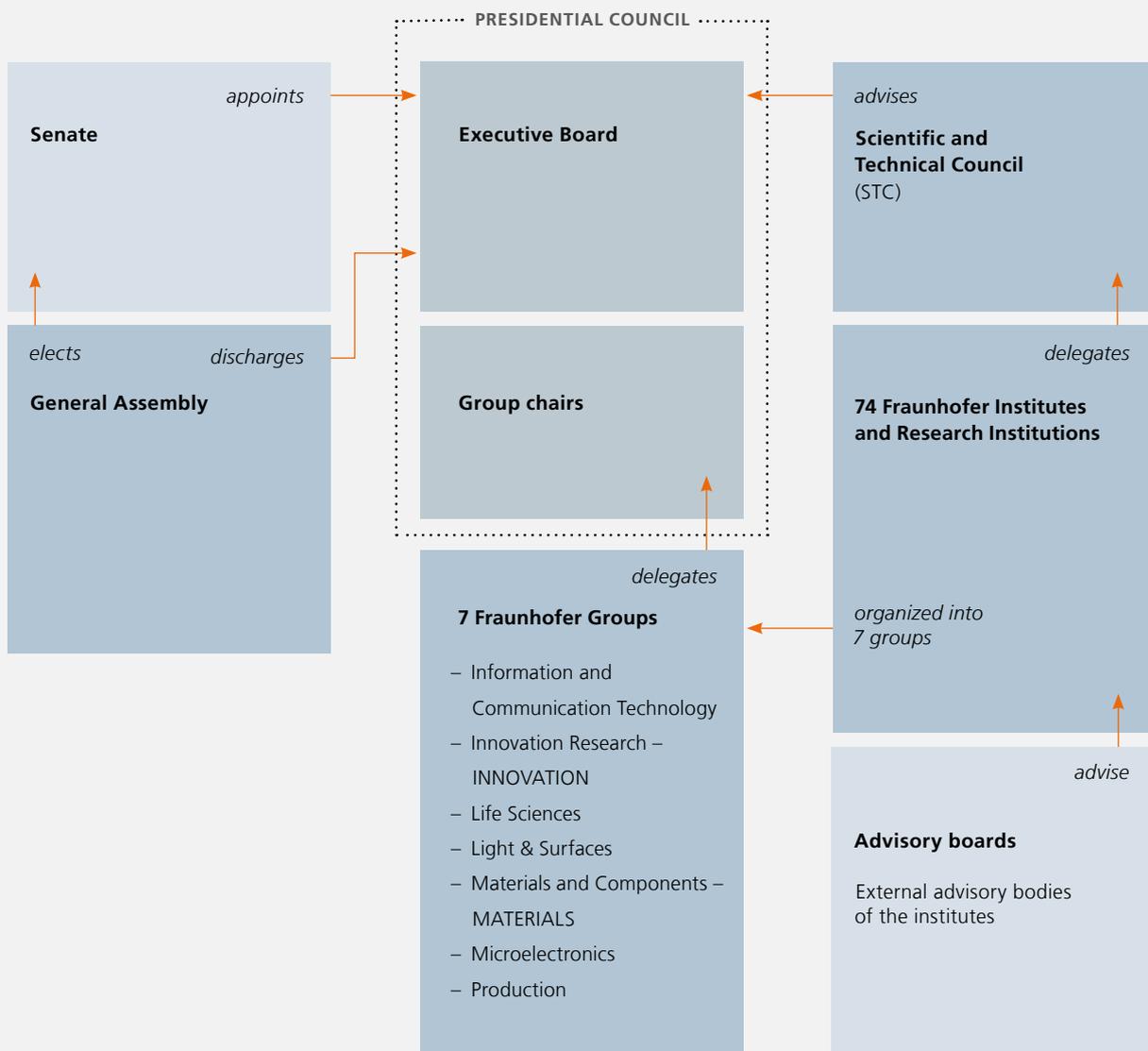
The **Senate** has around 30 members, comprising eminent figures from the worlds of science, business and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The Senate's duties include appointing members of the Executive Board, 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 and the Executive Board, institute directors and senior management, and members of 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 1196 members, comprising 229 ordinary members, 959 official members, 1 honorary senator and 8 honorary members. Some members have multiple functions.

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- 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
- Dr. rer. pol. Hans-Ulrich Wiese

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

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Deputy chair of the Senate of the Fraunhofer-Gesellschaft,
Director of Production and Technology, Bayerischer Rundfunk
- Oliver Zipse
Deputy chair of the Senate of the Fraunhofer-Gesellschaft,
CEO of BMW AG
- Dr. Oliver Blume
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- Dr.-Ing. E. h. Michael von Bronk
- Dr. Roland Busch
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- Reiner Hoffmann
President of the German Trade Union Confederation DGB
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- Natalie Mekelburger
President and CEO of Coroplast Fritz Müller GmbH & Co. KG
- Hildegard Müller
- Tankred Schipanski
Member of the German Bundestag, CDU/CSU parliamentary group

- Dr. Manja Schüle
(due to her appointment as Brandenburg State Minister of Science, Research and Cultural Affairs, only a member of the Senate from January 1 through February 10, 2020)
- Prof. Dr. Wiltrud Treffenfeldt

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- State secretary Susanne Bowen
State Ministry of Education, Science and Culture, Mecklenburg-Vorpommern
- State secretary Tobias Dünow
Brandenburg State Ministry of Science, Research and Cultural Affairs
- State secretary Andrea Franke
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- MinDirig Dr. Ole Janssen
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- Parliamentary secretary Thomas Rachel
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German Federal Ministry of Defence (BMVg)

Members delegated by the Scientific and Technical Council (STC)

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

Honorary senator

- Prof. Dr.-Ing. Dr.-Ing. E. h. Dr. h. c. Ekkehard D. Schulz

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
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- 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 838 members, some of whom hold seats on the advisory boards of more than one institute.

Scientific and Technical Council (STC)

The STC 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 STC:

- Prof. Dr. 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.-Ing. Jürgen Beyerer
Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB
- Prof. Dr. Karsten Buse
Fraunhofer Institute for Physical Measurement Techniques IPM

- Prof. Dr.-Ing. Welf-Guntram Drossel
Fraunhofer Institute for Machine Tools and Forming Technology IWU
- Prof. Dr. techn. Dieter W. Fellner
Fraunhofer Institute for Computer Graphics Research IGD
- Prof. Dr. Peter Gumbsch
Fraunhofer Institute for Mechanics of Materials IWM
- Prof. Dr.-Ing. Albert Heuberger
Fraunhofer Institute for Integrated Circuits IIS
- Prof. Dr. Horst-Christian Langowski
Fraunhofer Institute for Process Engineering and Packaging IVV

Executive Board

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(President)
- Prof. Dr. rer. nat. Ralf Boris Wehrspohn
- Prof. Dr. rer. publ. ass. iur. Alexander Kurz
- Dipl.-Kfm. Andreas Meuer

Listed information valid as at January 31, 2020

FURTHER INITIATIVES AND RESEARCH INFRASTRUCTURES

Fraunhofer 2022 Agenda and Future Commission

As part of the work being performed to develop the Fraunhofer 2022 Agenda, the Future Commission, which was set up in 2018, collaborated with many other internal units in 2019 to devise an organizational structure that will make the Fraunhofer-Gesellschaft fit to face the future. The aim is to give the organization a clear, less complex structure that will enable it to compete in the global research environment and also live up to the expectations of its stakeholders – namely policymakers, industry and the scientific community.

Impact Goals

The purpose of the Impact Goals is to help Fraunhofer hone its profile with policymakers, industry and society. The goals address social and cross-industry challenges and highlight the areas in which Fraunhofer can contribute significant solutions by taking an interdisciplinary approach:

- Affordable healthcare
- Energiewende accomplished
- Security and resilient society
- Digitalized value chain
- Fully circular economy

The following structural measures will be initiated in 2020: skills-based alliances, Fraunhofer Strategic Research Fields, and lead-market-oriented alliances.

Fraunhofer Strategic Research Fields

The Strategic Research Fields are the key areas constituting the Fraunhofer-Gesellschaft's research portfolio. They build on the impetus provided by the Key Strategic Initiatives, taking these initiatives to the next level. Taking relevance, strategy and priorities into account, Fraunhofer is positioning itself in the following interdisciplinary research fields:

- Artificial Intelligence
- Digital Healthcare
- Quantum Technologies
- Hydrogen Technologies
- Next Generation Computing
- Bioeconomy
- Resource Efficiency and Climate Technologies

Fraunhofer Groups

Within the Fraunhofer model, groups are places of solidarity and the joint utilization of resources. Their mission is to safeguard and evolve scientific excellence in their respective areas of expertise.

In 2020, each Fraunhofer Group will kick off a portfolio process, the goal of which is to record and structure the skills portfolio. The results of this process will be used to identify any necessary changes to the structure of each group and, possibly, to the group structure as a whole.

Lead-market-oriented alliances

Alliances are instruments that Fraunhofer uses to address industries that are key to Germany's and Europe's power of innovation. Above and beyond the individual institutes' R&D activities, Fraunhofer intends to set up lead-market-oriented alliances in order to generate system solutions and cross-institute offerings for selected industries – lead markets. Among other things, business plans and roadmaps will be drawn up to support strategic and cross-institute technology transfer. Activities will center around the interaction with relevant industry associations.

There were 22 active Fraunhofer Alliances in 2019. They are to be fundamentally restructured from 2020 onward. It is planned to address the following lead markets:

- Mechanical Engineering Industry
- Construction and Real Estate
- Chemical Industry
- Energy Sector
- Agriculture and Food Industry
- Healthcare Sector
- Digital Economy
- Mobility Sector

Former Fraunhofer Alliances that were not focused on a specific market, but on an area of scientific/technical research, may be continued in the form of thematic networks.

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.

Current lighthouse projects

- Evolutionary Self-adaptation of Complex Production Processes and Products – EVOLOPRO
- Cognitive Agriculture – COGNAC
- Medical Data Driving an Integrated Cost-Intelligent Model – MED²ICIN
- Machine Learning for Production – ML4P
- Quantum Methods for Advanced Imaging Solutions – QUILT
- Towards Zero Power Electronics – ZEPOWEL
- Sensor Systems for Extremely Harsh Environments – eHarsh
- Next Generation Additive Manufacturing – futureAM
- Digital Manufacturing – Innovative Integration of Digital Printing and Laser Processes for Mass Customization – Go Beyond 4.0

Completed lighthouse projects

- Combustion Engines for Tomorrow's Mobility – new drive systems, fuels and AI
- Electricity as a Raw Material – electrochemical processes for fluctuating energy and raw materials systems
- Theranostic Implants – approval-relevant development of key technologies for medicine
- Critical Rare Earths – efficient use of strategic high-tech metals
- Paradigm shift in production technology: Away from maximizing profit from minimum capital investment toward maximizing added value from minimum resources – E³ Production
- Electromobility – innovative technologies and components for hybrid and electric vehicles
- Cell-Free Bioproduction – developing an industrial process for cell-free protein production

Collaborations

Research Fab Battery Cells (FFB)

The idea behind this development center is to modularize the manufacture of large-format lithium-ion battery cells using digitalization strategies and to help replace conventional, rigid production lines.

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.

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 Federal Ministry of Education and Research (BMBF), 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.

National Research Center for Applied Cybersecurity ATHENE

ATHENE is an innovative, still unique form of collaboration in the field of university and non-university research. It examines key issues and problems in relation to cybersecurity and the protection of privacy rights, develops appropriate solutions, and provides corresponding assistance to businesses, the public sector, company founders and start-ups.

High-Performance Centers

Each based in a particular region, High-Performance Centers work together with university and non-university research partners to serve the needs of local industry.

- Center for Digital Connectivity, Berlin
- Chemical and Biosystems Technology, Halle-Leipzig region
- Connected Adaptive Production, Aachen
- DYNAFLEX®: Technologies for the Energy and Raw Materials Transition, Oberhausen
- Electronic Systems, Erlangen
- Functional Integration for Micro-/Nanoelectronics, Dresden/Chemnitz
- Integration of Biological and Physical-Chemical Material Functions, Potsdam-Golm
- Logistics and IT, Dortmund
- Mass Personalization, Stuttgart
- Mobility Systems, Karlsruhe
- Photonics, Jena
- Secure Smart Systems, Munich
- Simulation- and Software-Based Innovation, Kaiserslautern
- Smart Production and Materials, Chemnitz
- Sustainability, Freiburg
- Translational Biomedical Engineering, Hannover

International activities

New Project Centers in Shanghai, China

In 2019, Fraunhofer opened two Project Centers in China, both in cooperation with Shanghai Jiao Tong University (SJTU). Together with SJTU's Faculty of Mechanical Engineering, the Fraunhofer Institute for Manufacturing Engineering and Automation IPA founded the Fraunhofer Project Center for Smart Manufacturing, while the Fraunhofer Project Center for Urban ECO-Development was also inaugurated at SJTU. The Fraunhofer Institute for Building Physics IBP and SJTU's School of Design are performing joint research into innovative, smart and sustainable solutions for growing cities.

New Project Center in Jerusalem, Israel

The Fraunhofer Project Center for Cybersecurity and the Fraunhofer Project Center for Drug Discovery and Delivery were established in May 2019 in cooperation with the Hebrew University of Jerusalem (HUJI). These two centers combine the expertise of our Israeli partners at HUJI with that of the Fraunhofer Institute for Secure Information Technology SIT and the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB.

KI4Life innovation center in Klagenfurt, Austria

KI4LIFE, a Fraunhofer Austria innovation center for digitization and artificial intelligence in Klagenfurt, has been supporting local businesses in the state of Carinthia with digitization issues since October 2019.

Establishment of the European Defence Research and Innovation Network – EDRIN

Together with Dutch research facility TNO, French research partners ONERA and CEA, and the scientific organizations VTT in Finland and FOI in Sweden, Fraunhofer launched the European Defence Research and Innovation Network – EDRIN.

5G-Industry Campus Europe

The goal of 5G-Industry Campus Europe, which was launched by Fraunhofer and its research partners, is to carry out practice-oriented research and testing for the deployment of 5G wireless technology in the production environment.

Further initiatives

Industrial Data Spaces for data sovereignty

The objective of the International Data Spaces initiative is to create secure data spaces that enable companies of all sizes and from different industries to manage their data assets securely and independently.

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,” one of 10 projects selected to form part of the government’s High-Tech Strategy 2020.

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
- Microelectronic and Optical Systems for Biomedicine, Erfurt
- Project Center for Energy Storage and Management Systems ZESS, Braunschweig

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