

Annual Report 2020

For a secure future:
resilience through innovation

#WeKnowHow

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, headquartered in Germany, is the world's leading applied research organization. With its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry, Fraunhofer plays a central role in the innovation process. 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 systemic relevance, and to strengthen the German and European economy with a commitment to value creation that is based on ethical principles. 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 75 institutes and research units throughout Germany. The majority of the organization's 29,000 employees are qualified scientists and engineers who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros is generated through contract research. Around two thirds of Fraunhofer contract research revenue

is derived from industry contracts and from publicly funded research projects. The remaining one third 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 or 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 in dealing with contract partners.

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

Figures last updated: January 2021
www.fraunhofer.de

Annual Report 2020



For a secure future:
resilience through innovation



Foreword

Ladies and gentlemen,

2020 was shaped by the enormous efforts to tackle the COVID-19 pandemic. Fraunhofer faced the challenges with commitment, creativity and perseverance – knowing that through our work we will make a substantial contribution to starting up the economy again, to realigning it and to increasing its resilience in the coming years.

In the past year, the Fraunhofer-Gesellschaft was able to maintain and consolidate its role as a leading organization in applied research through its combined efforts and with support from the federal and state governments and the European Union. A stable performance whereby expertise was retained was achieved with a total business volume of around 2.8 billion euros. The scope of contract research stood at 2.4 billion euros. Fraunhofer has filed some 600 patent applications and more than 20 spin-off companies have been set up – further testimony to our enduring success even in trying times.

Expertise, staff levels and operational continuity were maintained at the institutes and headquarters during the pandemic. The approximately 29,000 employees and managers form the basis for this stability and are highly motivated, performing their scientific, organizational and administrative work with impressive resoluteness and complete dedication every day. On behalf of the Executive Board as whole, I would like to sincerely thank the entire staff for their excellent contribution!

The pandemic continues to be a practical test for us. In order to fully play our role as guarantor of the technological leadership and technological sovereignty of Germany and Europe, we ourselves must also display a high degree of resilience. Resilience means being able to withstand, in combination with having the ability to recover and to be able to use a crisis to advance further through innovation. This is of major significance for the welfare of all people in a company, for the company itself, for regions, nations and all of society. In our work, we therefore prioritize the topic of resilience as a decisive factor in international competition and have dedicated a detailed report to it in this annual report.

In order to maintain performance at the Fraunhofer-Gesellschaft in the long term and to increase it further, we follow the recommendations of the Future Commission appointed by the Executive Board as regards setting a strategic course of action. This includes the further development of scientific excellence through expertise-based groups and the definition of systemically relevant research focuses in the form of Fraunhofer Strategic Research Fields (FSF). By cultivating lead-market-oriented alliances, we also pursue the objective of directly addressing sectors that are highly relevant in terms of the innovative power of Germany and Europe, and of providing them with system solutions.

In the scientific system, we continue to stand for excellence in research and in the transfer of results into practice with the objective of achieving a sustainable industrial society that is oriented toward a circular economy, resource efficiency and bioeconomy. One of the most important objectives of our work also includes affordable healthcare for

everyone. And we are making a substantial contribution to accomplishing the energy transition – three objectives that we are actively pursuing with the aid of three new relevant Fraunhofer Groups. Fraunhofer is a proven center of expertise in hydrogen technologies that are needed for the reorientation of energy supply, and it is intensively engaged in the further development of these technologies and their implementation in areas of application.

We are pursuing the goal of increased, digitalized value creation in the knowledge that data security and the associated data sovereignty are absolute prerequisites for broad acceptance of these technologies. Digital technology is, of course, also just as important for the aforementioned resilience and the security of society as a whole, as practically all relevant infrastructures today are functionally based on digital technologies.

By incorporating new work elements, we also create a flexible, cooperative, participatory and customer-oriented working and research environment for independent employees – in the knowledge that our attractiveness on the market for highly qualified personnel as well as the consistently high motivation of the entire staff are decisive factors for our stability and success.

We are grateful to our partners from the spheres of politics, the economy and society for the constant trust they have placed in us in these times of crisis, and we look forward to continued fruitful collaboration based on common values and objectives.

Sincerely,

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

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft

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Resilience through ensuring
basic needs: high-quality and
sustainably produced food
in accordance with the latest
scientific findings.



Resilience for complex structures:
safeguarding the capacity of our
infrastructure through innovative
concepts.





Report of the Executive Board

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The Executive Board



Reimund Neugebauer

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



Andreas Meuer

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 has been a member of the Fraunhofer Executive Board since early 2018.

Dipl.-Kfm.

Andreas Meuer

Executive Vice President, Finances and Digitalization



Alexander Kurz

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

Management report 2020

Strategy and operating environment

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Fraunhofer-Gesellschaft – key data for 2020 (in € million)

	2019	2020	Change	
Total business volume	2760	2832	+72	+3%
Contract research	2295	2398	+103	+4%
Additional research funding	159	164	+5	+3%
Major infrastructure capital expenditure	306	270	–36	–12%
Business volume by budget	2760	2832	+72	+3%
Operating expenses	2279	2357	+78	+3%
Capital expenditure ¹	481	475	–6	–1%
Project revenue	1756	1716	–40	–2%
Contract research	1549	1553	+4	+0%
of which industrial revenue	724	658	–66	–9%
of which public-sector revenue ²	825	895	+70	+8%
Additional research funding	79	76	–3	–4%
Major infrastructure capital expenditure	128	87	–41	–32%
International project volume³	296	276	–20	–7%

¹ Current capital expenditure for contract research, additional research funding and major infrastructure projects.

² Comprises German federal and state government, EU and other revenue.

³ Excludes license-fee revenue and revenue generated by legally independent international Fraunhofer affiliates through business with third parties (2020: €24 million).

Strategy and operating environment

Profile of the Fraunhofer-Gesellschaft

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 75 Fraunhofer Institutes and Research Institutions in Germany employ around 29,000 people who generate an annual business volume of €2.8 billion. **Contract research** accounts for €2.4 billion of this total. Fraunhofer derives around two thirds of this revenue from industry contracts and from publicly funded research projects. The remaining third is provided by 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.

At an organization-wide level, Fraunhofer identifies innovative areas of business and trending technologies with significant market potential and relevance to society and establishes **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.

In order to coordinate their R&D strategies, Fraunhofer Institutes that conduct contract research in related areas of technology were organized at the reporting date into seven **Fraunhofer Groups**:

- ICT Group
- Innovation Research – INNOVATION
- Life Sciences
- Light & Surfaces
- Materials and Components – MATERIALS
- Microelectronics
- Production

Adjustments were made to group structures on January 1, 2021 for the purposes of improving Fraunhofer's competence profile and strengthening competitiveness (see the sections "Creating opportunities through strategic initiatives" and "Outlook").

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

Creating opportunities through strategic initiatives

At the end of 2019, the Fraunhofer Future Commission, which comprises the Executive Board, 12 institute directors and managers from headquarters, put forward a number of recommendations for adjusting the management and the internal structure of Fraunhofer. On the basis of these recommendations, the Executive Board took strategic decisions in January 2020 to safeguard the future viability of Fraunhofer.

The growth of Fraunhofer and the related dynamic expansion of its R&D portfolio in terms of breadth and depth requires this portfolio to be developed at both corporate and group level. The future objective of the groups is thereby to ensure the coherence of research activities conducted across the institutes and to communicate the scientific excellence of the Fraunhofer-Gesellschaft to the wider public. In 2020, the **"Competence-Oriented Groups"** project had the aim of demonstrating the groups' expertise in a homogeneous way while establishing a comprehensive Fraunhofer-wide portfolio of experts. It is anticipated that raising the Fraunhofer profile, realigning group structures and establishing additional groups will reinforce the strategy for research areas related to future technology. For instance, the "Life Sciences" group will be restructured into the three new groups: "Energy Technologies and Climate Protection," "Resource Technologies and Bioeconomy" and "Health."

For more than 15 years, the Fraunhofer Institutes have been regularly conducting **standardized strategy processes** to adapt their research fields and strengthen their focus. These processes were modified in 2020 in order to strengthen cross-institute cooperation, give greater consideration to stakeholder expectations and to assure the quality of demand-driven

expertise development. The Fraunhofer strategy process is characterized by streamlined and flexible management, as well as iterative planning between the management of institutes and departments and between the hierarchical levels. Linking different hierarchical levels also offers opportunities for strategy development across institutional borders.

The **High-Performance Centers** form a central transfer structure and primarily provide R&D services in key technological fields for small and medium-sized enterprises. In 2020, 16 of the original 17 High-Performance Centers were in existence, with the High-Performance Center Security and Privacy in the Digital World (Darmstadt) having been transferred to the National Research Center for Applied Cybersecurity ATHENE in 2019.

With the development of the **Fraunhofer Strategic Research Fields (FSF)**, Fraunhofer aims to be a leader in future-oriented research fields with strong exploitation potential. The following topics represent research fields:

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

These FSF were established in 2020 and selected on the basis of systematic processes informed by foresight and technology intelligence, including analysis conducted by institutes from the Fraunhofer Group for Innovation Research – INNOVATION. This analysis included competitive analysis, elements of crowd research and data science methods. Relevance for business (in particular for small and medium-sized enterprises – SME) and society, scientific excellence and strategic priority constituted the main criteria.

To advance applied research in quantum computing, the Fraunhofer-Gesellschaft has established the centrally coordinated **"Fraunhofer Competence Network Quantum Computing."** At the heart of the network is the IBM Q System One quantum computer, which is installed in Ehningen in Baden-Württemberg for use exclusively by the Fraunhofer-Gesellschaft and its partners. The quantum computer has been in operation since early 2021 and is operated under German legislation, which is an important advantage in terms of data protection and IP security. Since April 2020, cloud access to IBM quantum computers was already available in the U.S. The network is divided into seven regional competence centers, each with its own research focus. These regional competence centers work closely with partners and customers from research and industry.

With the **"Sustainable Subsea Solutions ISSS"** innovation platform, the Fraunhofer-Gesellschaft has given the topic of marine sustainability greater prominence on the European level. The ISSS envisions a sustainable use of the world's oceans that ensures food and resource sovereignty for Germany and the EU and simultaneously protects the oceans as a core element of the global ecosystem. In particular, the ISSS focuses on aquaculture for food products, animal feed, pharmaceuticals and cosmetics as well as on offshore energy generation. Cleaning the oceans of microplastics, macroplastics and dumped munitions are also ISSS goals. In addition, reliable digital underwater technology is under development as an enabling technology for the marine economy. The ISSS consortium currently encompasses seven additional European applied research institutions in addition to Fraunhofer.

As a reaction to the current crisis, the German federal government resolved to support non-university research institutions in order to prevent the discontinuation of ongoing research. This is outlined in their pact for the future in the key issues paper "Combating the consequences of Corona, securing prosperity, strengthening sustainability." The Fraunhofer Executive Board also initiated the **"Fraunhofer Innovation Program"** in May 2020. This program aims to provide a structure for innovative projects from different institutes and address areas of expertise that are affected in particular by the current economic crisis and have added value for securing the future of the institute as well as for helping to restart the economy. Consortia were set up within a few weeks and since then have started collaborative initiatives with a high degree of synergy in research fields such as Green ICT, trusted electronics and digital pharmaceutical production. Funds were allocated in two installments to 13 projects. Future technologies that can assist in building and maintaining technological sovereignty within interlinked global supply and value creation chains are a point of focus, as are technologies in the area of climate neutrality and resource recycling.

The total number of institute heads and other managers at Fraunhofer with **connections to a university or university of applied sciences** rose from 221 in 2016 to 263 in 2020, with Fraunhofer staff spending around 9200 semester hours per week in teaching. In this way, the Fraunhofer-Gesellschaft is making an important contribution to the achievement of skills in the tertiary education sector while also equipping students with the latest knowledge from applied research.

Science policy framework

Through 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.



Chaired jointly by Prof. Reimund Neugebauer and Christian Luft, state secretary at the German Federal Ministry of Education and Research (BMBF), the **High-Tech Forum** is a group of experts from the fields of economy, science and society that advises the German federal government on the implementation of its High-Tech Strategy 2025. Recommendations by the group published in a 2020 paper advised the German federal government on agility within the innovation system and the role of the state as actor, the future of value creation, sustainability within the innovation system, innovation and qualifications, open science and innovation and bio-IT innovations. In its "Innovation policy after the coronavirus crisis: Seven guidelines for new growth" paper, published in early June 2020, the High-Tech Forum also notes the historic opportunity for the government's economic stimulus package, which includes a comprehensive set of measures to invest in Germany's future, to effect a fundamental shift towards a new and qualitative system of growth.

Members of the advisory committee held conversations with executive and legislative political authorities at meetings held to present and discuss their recommendations with state secretaries from all federal ministries, and at parliamentary events with members of the German Federal Parliament (Bundestag).

The High-Tech Forum will submit its final recommendations for developing the current strategies it has proposed during the coming legislative period to Federal Minister Anja Karliczek in April 2021. It will hold an interactive, in-depth discussion in the format of a TV magazine program on the topics on resilience and openness, promoting innovation in Germany and the role of co-creation in a sustainable innovation strategy.

The **Innovation Dialog** is led by Chancellor Angela Merkel and serves as an independent, confidential advisory board on questions related to innovation policy and measures for the future. Chancellor Merkel and other members of cabinet held a virtual meeting in June 2020 with the steering committee, of which Professor Neugebauer is a member. The topic on the agenda was "Innovative measures towards a European Green Deal." The exchange focused on green innovation as a driver for transforming industry and as an instrument for sustainable investment and corporate activity. Core Fraunhofer thematic fields also discussed were biological transformation and hydrogen as key elements for the sustainable restructuring of the economic system in line with a Green Deal.

At the most recent summit in January 2021, the main topic of discussion was "The resilience of supply chains and value creation networks." Against the backdrop of the SARS-CoV-2 pandemic, participants discussed the resilience of economic structures with a view to securing value creation and employment in the long term and to guaranteeing Germany and the

EU's capacity to act in times of crisis. Core elements of the quantum computing roadmap also took center stage in the debate on innovation policy. At the final session of the 19th Bundestag, which is due to take place in July 2021, the focus will be on looking ahead – to opportunities for advancing the German innovation system and for translating cutting-edge ideas from research and development into sustainable and internationally competitive business models.

June 3, 2020 saw the German federal government introduce an **economic stimulus package** of €130 billion to overcome the coronavirus crisis. This package includes a comprehensive set of measures to invest in Germany's future. Particular fields of the future that have received funding through the package are hydrogen technology with funding of €7 billion, quantum technology with €2 billion and artificial intelligence, also with €2 billion. These fields fall under the jurisdiction of the German Federal Ministry of Education and Research (BMBF). Research-based companies will also receive increased support in terms of tax incentives for research funding, with a doubling of eligible expenses. Companies can now claim up to €1 million in tax relief on research expenses.

A supplementary budget approved in early July 2020 by the German Federal Parliament and German Federal Council within the framework of the economic stimulus package provided €1 billion in funding support to non-university research institutions for the purposes of maintaining and strengthening research collaborations with the commercial sector. These measures have been introduced to fulfill the government's aim of achieving rapid economic results for business sectors focused on technology and innovation, in particular SMEs. Funding amounting to €400 million from the BMBF budget was made available for non-university research in 2020. This allowed for the compensation of losses in funding up to the amount of the discontinued corporate funding and retention of the expertise of non-university research institution staff.

With a clear focus on retaining its staff levels and their expertise, the Fraunhofer-Gesellschaft requested an additional allowance from the federal government on September 30, 2020 to cover a shortfall of €206 million resulting from the coronavirus pandemic and the corresponding reduction in revenue from industry. This request was made in line with the BMBF budget item 3004/685 01 clause 2.1 in relation to applied research support for non-university research organizations. The BMBF approved an allowance of a total of just under €195 million in two stages in November and December 2020.

Three new Fraunhofer initiatives were approved during subsequent budgetary negotiations in the German Federal Parliament in November 2020. With an overall funding allowance of €80 million, the Fraunhofer Center for Biogenic Value Creation and Smart Farming is now able to pool together the

research of five Fraunhofer Institutes and continue advancing technology for developing sustainable, highly customized and automated systems of agriculture. Similarly, with an allocation of €175.5 million, we were able to create a Fraunhofer Cluster of Excellence for boosting research activities in immune-mediated diseases through technologies for the prevention, diagnosis and treatment of immune and infectious diseases. Finally, a Fraunhofer center for public safety and security was set up with €71.1 million of the funding support. This center will focus on researching and developing technologies that will enable police and authorities who are responsible for security to ensure public safety in Germany.

Business report

Total business volume

With tremendous input from everybody involved, the Fraunhofer-Gesellschaft succeeded in overcoming the effects of the coronavirus pandemic in 2020. Total business volume remained stable year-on-year at €2.8 billion, which confirms that Fraunhofer has been successful in retaining its staff levels and expertise. Contract research accounted for 85 percent of this sum (around €2.4 billion) and represents the organization's core activity. Around one third of contract research funding is provided by base funding from the federal and state governments. 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 €164 million in the reporting period. Major infrastructure capital expenditure amounted to €270 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-purpose 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 2020, Fraunhofer invested a total of €475 million, a 17-percent share of the total business volume. Personnel expenses increased to €1565 million. In addition to a 1-percent increase in pay from March 1, 2020, the number of employees increased, despite a board resolution that froze recruitment from April 15, 2020 and only permitted new staff to be hired in individual cases where this was strategically necessary, or where externally specified measures required it. At €792 million, non-personnel expenses were slightly higher than in the previous year. While significant savings were made due to the coronavirus, for example in terms of travel costs, establishing the new Fraunhofer Competence Network Quantum Computing resulted in additional non-personnel expenses. The reserve fund balance remained unchanged in 2020; however, it was used in the course of the year to cover liquidity requirements.

Contract research

For Fraunhofer, contract research is the mainstay of its business activities. Based on the **Fraunhofer model**, it consists of three pillars, each contributing equal amounts to the organization's finances:

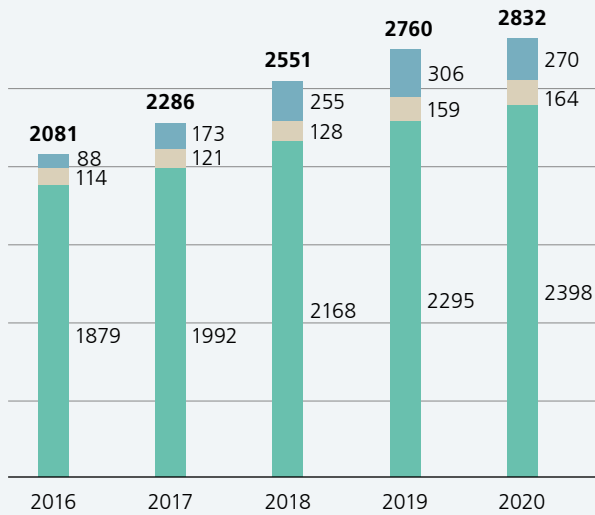
- Research directly contracted by industry
- Publicly funded research projects
- Pre-competitive research funded with base funding

The amount of base funding used to finance pre-competitive research increased by 13 percent to €845 million in 2020 due to the coronavirus. Base funding is provided by the German Federal Ministry of Education and Research (BMBF) and the state governments in a ratio of 90:10. An additional €195 million in federal government funding for supporting applied research by non-university research institutions enabled Fraunhofer to establish measures for retaining expertise. These include such as setting up internal funding programs for meaningful research contributions to overcoming the coronavirus pandemic. There was a significant decline in industrial revenues. On account of the crisis, they fell 9 percent to €658 million. Additionally, revenue from industry contracts fell by 9 percent to €559 million and license-fee revenue dropped by 7 percent to €99 million.

In contrast, there was a significant increase in **revenue from publicly funded projects**, which was an essential pillar of support in a time of crisis. Project funding from state governments, in particular, jumped by 22 percent to €196 million. Project funding from the federal government grew by 6 percent to €485 million. However, EU revenue decreased slightly to €92 million. With its participation in the European Union's Horizon 2020 Framework Program for Research and Innovation, Fraunhofer is actively engaged in shaping European business and research and continuously holds a top position (currently 3rd place) in rankings for R&D research institution funding. Other revenue increased by 8 percent to €122 million, and includes funding granted by foundations, universities and other research-funding institutions.

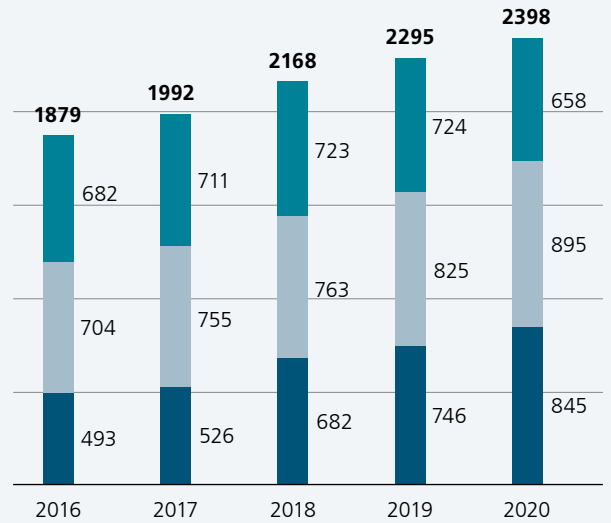
The high **funding ratio of external project revenue** marks the success of the Fraunhofer Institutes and is a distinguishing feature of the Fraunhofer-Gesellschaft. The project funding ratio therefore serves as a key performance indicator and as a

Fraunhofer total business volume in € million



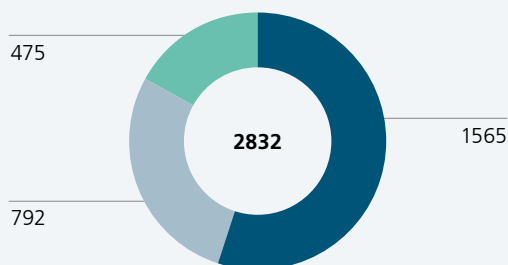
- Major infrastructure capital expenditure
- Additional research funding
- Contract research

Revenue from contract research in € million



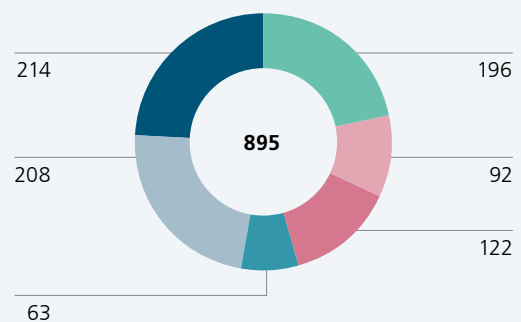
- Industrial revenue
- Revenue from publicly funded projects
- Base funding

2020: Total business volume by budget in € million



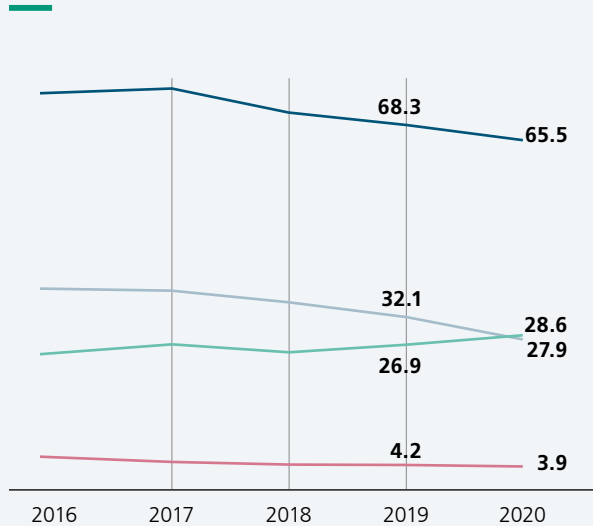
- Personnel expenses
- Non-personnel expenses
- Capital expenditure

2020: Revenue from publicly funded projects in € million



- BMBF
- BMWi
- Other federal ministries
- Federal states
- EU
- Other

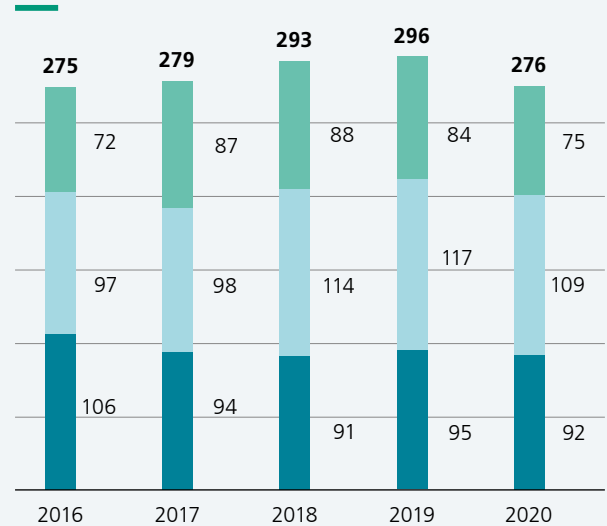
Funding ratio in %



- Total project revenue¹
- Industry
- Federal and state governments
- EU

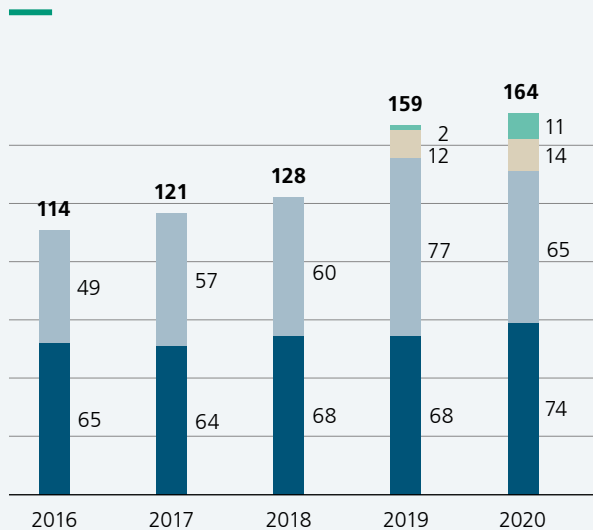
¹ Includes other sources of revenue, 2020: 5.1%.

International project volume in € million



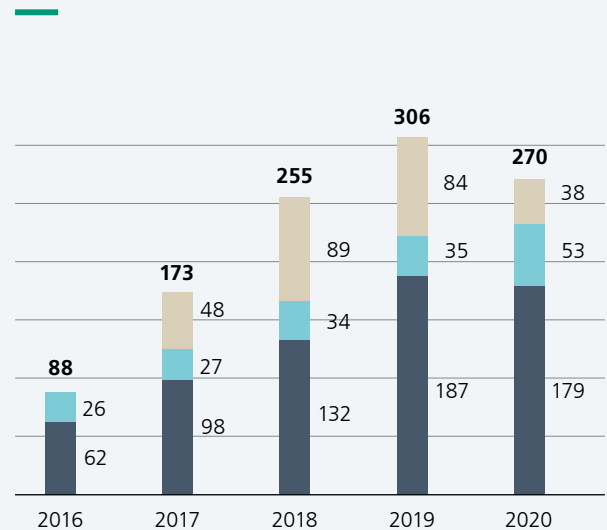
- Customers and partners outside of Europe
- Customers and partners within Europe
- EU project funding

Additional research funding in € million



- FFB project funding (BMBF)
- ATHENE base funding (BMBF and Hessen)
- BMVg project funding
- BMVg base funding

Major infrastructure capital expenditure in € million



- Research Fab Microelectronics Germany (FMD)
- Equipping of new facilities
- Building projects (major and minor)

barometer for establishing an optimal funding mix for contract research. It is calculated as the share of external project revenue in the operating budget, including imputed write-downs on investments (excluding initial funding for newly established facilities and excluding changes in reserves). For a long period of time, the external revenue generated as a result of the growth in demand for Fraunhofer services was higher than the potential increase in base funding. A one-time, permanent increase in base funding in 2017 meant that the funding ratio declined in subsequent years as planned and in 2018 and 2019 it was again in line with the Fraunhofer funding model. In 2020, the project funding ratio fell by a further 65.5 percent as a result of the coronavirus pandemic. A sharp increase in revenue from federal and state governments resulted in their funding ratio rising to 28.6 percent. In contrast, the share of industrial revenues sank to 27.9 percent as a result of the crisis.

Due to the coronavirus, **the international project volume** decreased for the first time in several years by 7 percent to €276 million (excluding license-fee revenue), with its share of total project funding for contract research falling slightly year-on-year to 18 percent. 33 percent of international project volume came from EU funding, 40 percent from customers and partners in Europe and 27 percent from those outside of Europe. The amount of project volume generated within Europe decreased by 7 percent to €109 million, while project volume generated outside of Europe fell by 11 percent to €75 million. Switzerland, at €29 million, remained the largest market outside of Germany, followed by the USA (€26 million) and Japan (€17 million).

Additional research funding

Additional research funding covers long-term research efforts that are not financed by means of base funding. In addition to established defense-related research, the National Research Center for Applied Cybersecurity **ATHENE** and the **Research Fab Battery Cells FFB** fall under additional research funding.

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 the fields of law, economics, psychology and ethics. **ATHENE** is funded by the BMBF and the state of Hessen in a ratio of 70:30 and recorded a slightly increased budget of €14 million in 2020.

€11 million was spent in 2020 on **setting up the FFB**. This amount will increase substantially in the coming years.

Developing the FFB is a major pioneering project of national significance for Germany and will receive around €500 million in funding from the BMBF in the next years. 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.

Seven Fraunhofer Institutes involved in research and development (R&D) in the area of **defense research** are grouped together and receive base funding and ongoing project funding from the German Federal Ministry of Defence (BMVg). 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. Although base funding from the BMVg rose by €6 million to €74 million, ongoing project funding from the BMVg fell by €12 million to €65 million. This was due to delays in the allocation of several project grants, which could not be made up by the end of the year. Funding for defense research thus fell overall by 4 percent to €139 million.

Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises building projects and the purchase of scientific instruments and furniture to equip new facilities. It also includes expenditure on the **Research Fab Microelectronics Germany (FMD)**. Following significant increases in recent years, major infrastructure capital expenditure in 2020 dropped to €270 million euros.

The main reason for this is the scheduled completion of the **FMD** and the associated decrease in expenditure on equipping the new facilities to €38 million. The BMBF has provided €350 million in funds towards the project to set up the FMD, with Fraunhofer receiving €280 million of this sum and the two participating 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 in total by 5 percent compared with the previous year. While funding for building projects decreased by €8 million to €179 million, of which major building projects received €153 million and minor projects €26 million, capital expenditure on equipping new facilities rose by €18 million to €53 million. Special funding for major building projects and the equipping of new facilities 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 base 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 base funding from the federal and state governments totaled €183 million. ERDF funds from the states accounted for €45 million of project revenue, while €4 million was accounted for by other revenue.

Financial and net asset position

As of December 31, 2020, the Fraunhofer-Gesellschaft had total assets of €3943 million, up €235 million or 6 percent on a year-on-year basis. 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 €154 million higher at €2473 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 €158 million to €2408 million.

Current assets accounted for 35 percent of assets and were €75 million higher at €1384 million. In addition to receivables from federal and state governments through project billing (excluding contracts) increasing by €23 million to €227 million, there was an increase of €10 million in receivables from affiliated companies. Cash and cash equivalents (including bank account balances) increased by €9 million to €100 million. The value of the securities portfolio was €25 million higher, at €441 million. €416 million of this reserve fund was license-fee revenue and €25 million corresponded to the special reserve for financing restructuring measures.

Equity – which comprises the non-profit organization's capital that is not financed by government grants (€15 million) and the reserve for statutory purposes (€18,825) – increased by a marginal amount. Economic equity also includes four kinds of special reserve recognized in the balance sheet: The special reserve for grants relating to non-current assets was €155 million higher at €2461 million. The special license-fee revenue reserve for statutory purposes remained unchanged from the previous year at €416 million. The special reserve for the present value of deferred income from a patent deal came in at €54 million. This reserve is matched by other receivables of an equivalent amount on the assets side of the balance sheet.

For the first time, a special reserve of €25 million was created in 2020 for the necessary restructuring of cleanroom infrastructure. This reserve is matched by securities of an equivalent amount on the assets side of the balance sheet. Use of these funds is tied to a restructuring plan and contributes to the development of the main sites of Fraunhofer Institutes and

their secondary locations. The aim is to reduce fixed costs while also enhancing cooperation and the quality of services.

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 €325 million at the reporting date.

Provisions increased by €2 million to €199 million, €49 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 €85 million was entered on the assets side of the balance sheet.

Liabilities rose by €4 million to €445 million. In addition to an increase of €19 million in unappropriated grants from federal and state governments from base funding and project billing, trade payables and other liabilities fell by a total of €14 million. Other liabilities includes taxes amounting to €9 million. 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 and can use its reserves as needed. Even in times of crisis, Fraunhofer's funding model offers a solid foundation.

Shareholdings and spin-offs

At the reporting date, the Fraunhofer-Gesellschaft held equity investments in a total of **86 companies** operating in a diverse range of sectors. The transfer of technology to industry formed the focus of activities at 61 of the companies in the investment portfolio, while a further 19 equity investments were of a strategic nature. Equity investments also include six affiliated companies. Within the Fraunhofer investment portfolio, there was a lower level of activity in 2020. Overall, the Fraunhofer-Gesellschaft spent some €1.9 million on the acquisition of equity interests. The Fraunhofer-Gesellschaft added three companies to its investment portfolio and divested its shares in seven. The total carrying amount of equity investments (including shares in affiliated companies) increased to €9.1 million (2019: €8.6 million). Income from the divestiture of equity investments came to €1.3 million.

For Fraunhofer, **spin-offs** are an integral part of the organization's strategy for exploiting its industrial property rights. The Fraunhofer Venture department of the Fraunhofer-Gesellschaft

usually 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 2020, Fraunhofer Venture provided support to 64 new spin-off projects; in total, 26 new businesses were spun off from the Fraunhofer-Gesellschaft. The goal for Fraunhofer is to not only increase the number of spin-offs but also their proportional contribution to revenues from industry. Our innovation hub AHEAD offers a comprehensive package of targeted measures and programs to help achieve this.

International activities

The Fraunhofer-Gesellschaft 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** represent the most institutionalized form of such partnerships:

- 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 (Sweden)
- Fraunhofer Singapore Research Ltd.

These legally independent international Fraunhofer affiliates are constituted under the laws of their country of domicile and function as the legal entities supporting Fraunhofer research centers outside of Germany, which number 15 at the reporting date. The latter are institutionalized partnerships between Fraunhofer and local universities, enabling long-term research activities abroad. As their work is not profit-oriented, these companies generally qualify for base funding from their country of domicile, and are financed in line with the Fraunhofer model. As part of the Fraunhofer internationalization strategy, these legally independent international Fraunhofer affiliates will take on a new strategic role. In the future, greater emphasis will be placed on promoting two-way scientific collaboration between the Fraunhofer research centers outside of Germany and the Fraunhofer Institutes based in Germany. In addition to project revenue generated by the Fraunhofer-Gesellschaft with

customers outside of Germany, the legally independent international Fraunhofer affiliates generated third-party revenues amounting to €24 million in 2020. Of this amount, Fraunhofer USA alone accounted for €8 million, followed by the Stiftelsen Fraunhofer Chalmers Centrum för Industrimatematik (Sweden) and Fraunhofer Austria, each with €4 million. Revenue generated through research activities by the legally independent international Fraunhofer affiliates was just under €60 million in 2020. Fraunhofer research centers outside of Germany have a broad spectrum of research activities, encompassing quantum technology as well as IT, artificial intelligence, industrial mathematics, manufacturing and logistics, biotechnology and solar energy technology.

The **Fraunhofer Innovation Platforms (FIPs)** – formerly called Fraunhofer Project Centers (FPCs) – are vehicles that enable Fraunhofer Institutes to collaborate with research organizations outside of Germany on a specific topic for a limited period of time. In each case, the partner organization sets up the FIP as a local legal entity and cooperates closely with a Fraunhofer Institute in Germany on the chosen topic. The aim of this form of collaboration is to carry out joint research, including projects for customers, and take part in projects funded by the public sector. 2020 saw the establishment of the “Fraunhofer Innovation Platform for the Water-Energy-Food Nexus” (FIP-WEF@SU), a cooperative project between Stellenbosch University in South Africa and the Fraunhofer Institutes IGB, IST, ISE and IOSB. The FIP-WEF@SU is dedicated to research and technology development in the areas of water, energy and nutrition.

The Fraunhofer internal program **ICON (International Cooperation and Networking)** enables strategic project-based partnerships with international universities and non-university research institutions of excellence. The new cooperative project PACIFIC (Scale-up of Plasma Coating Processes for Programmable Thin Film Coatings) between Fraunhofer IFAM and Stanford University (USA) was established in 2020. The project has the goal of improving the environmental footprint of glue-based products.

In addition to already established forms of cooperation, four new international projects with partners of excellence were created in 2020, two of these projects are with the Netherlands Organization for Applied Scientific Research (TNO). The first project, “Value-oriented Design and Enforcement for Responsible Automated Decision Making”, will develop approaches for making artificial intelligence more reliable from a legal, ethical and technological perspective. The TNO's cooperation partner is Fraunhofer IOSB. The second project is a cooperation between TNO and the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES that explores new intelligent infrastructure for implementing the transition to a new energy economy.

Two additional projects were set up in South Africa and Italy. The Repair Technologies for Carbon Fiber Reinforced Aircraft Structures (ReCarbo) project is run jointly by Fraunhofer IWU, Nelson Mandela University and Aerosud Aviation Ltd. (South Africa). Fraunhofer IWU is working in collaboration with the University of Naples Federico II to combine and develop soft robotic systems with cognitive functions.

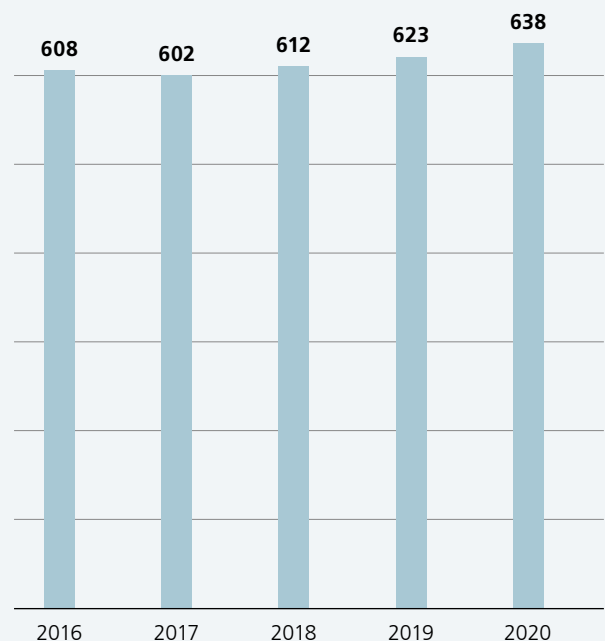
The **Fraunhofer International Mobility Program (FIM)** was created to encourage international mobility and networking among Fraunhofer employees and to support knowledge transfer. The program was expanded in 2020 and now facilitates stays abroad at universities and non-university research institutions outside of Germany in addition to stays at the international locations of the global Fraunhofer network. Fraunhofer employees from all fields of activity and at any career stage can opt for a stay abroad lasting between eight weeks and five and a half months. The FIM serves as a means of enhancing cooperation between Fraunhofer Institutes located in Germany and the Fraunhofer network worldwide. Stays abroad that have been postponed by the coronavirus pandemic will go ahead as soon as possible.

International Fraunhofer representative offices in China, Brazil, India, Japan and Korea function as a hub for networking and marketing. They support all Fraunhofer Institutes on the ground in initiating and setting up cooperations with local research partners from the respective countries. Types of cooperation include publicly funded projects as well as industry projects. With their knowledge of the local research landscape, representative offices are able to create new opportunities for expanding the Fraunhofer research portfolio. Senior advisors in Ireland, Italy, Hungary, Israel, South Africa and Malaysia have roles with similar responsibilities.

Exploitation of intellectual property rights

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. The performance achieved by the Fraunhofer-Gesellschaft is outstanding even when compared with that of industrial research laboratories. Over the last decade, Fraunhofer has always ranked among the German Patent and Trade Mark Office's 10 to 20 most prolific patent applicants. Fraunhofer is also among the European Patent Office's most active patent applicants. In 2020, employees of the Fraunhofer-Gesellschaft submitted 753 invention disclosure reports. They filed 638 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. The Fraunhofer portfolio of active patent families, each of which comprises all intellectual property rights in different countries,

Patent applications claiming rights of priority



rose to 7667. To guarantee a continuous flow of revenue from the exploitation of intellectual property rights, patents owned by different institutes are increasingly being grouped together into application-specific portfolios that are then offered to 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 include patents for audio and video encoding. The pools – which not only include Fraunhofer patents relevant to standardization, but also patents 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 2020, Fraunhofer concluded 352 new IP exploitation agreements, bringing the total number of active agreements at the end of the year to 2924. Due to the expiry of a number of licensed patents, license-fee revenue in 2020 once again declined year-on-year, but still remained high at €99 million.

Selected aspects of corporate responsibility

Responsibilities of the Fraunhofer-Gesellschaft

Fraunhofer sees corporate responsibility (CR) as an **all-encompassing term** that covers the economic, environmental 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 way it focuses its research on generating benefits for society and promoting Germany's and Europe's industrial strength.

Fraunhofer clearly demonstrated its willingness to assume responsibility in 2020 in its handling of the global coronavirus pandemic, which also posed particular challenges for the Fraunhofer-Gesellschaft. The organization introduced extensive measures to protect its employees, such as immediately implementing a wide range of protective and hygiene measures and enabling more flexible ways of working, including the option to work from home. In addition, Fraunhofer research itself was firmly focused on combating the pandemic. Under the slogan **"Fraunhofer vs. Corona,"** Fraunhofer set up the internal **"Anti-Corona"** emergency program over April and May 2020. This program earmarked funding from medical and health projects for the rapid generation of solutions aimed at tackling the SARS-CoV-2 pandemic. Examples of these include projects that provide urgent support for labs, support for developing vaccinations and medicine and the use of Fraunhofer IT capacities to provide information to the public and to authorities.

As the world's leading applied research organization, the Fraunhofer-Gesellschaft also delivers sustainable solutions to meet society's future needs. To ensure that these contributions can continue in the long term, Fraunhofer has implemented a future-proofed structural approach for attaining the following five goals for the whole of society: 1. Affordable healthcare, 2. Energiewende accomplished, 3. Digitalized value creation, 4. Fully circular economy and 5. Security and resilient society. These goals set out social and cross-industry challenges to which Fraunhofer can contribute meaningful solutions.

As key structural elements underpinning delivery of these solutions, **seven new Fraunhofer Strategic Research Fields (FSF)** were initiated, including FSF Bioeconomy, which aims to develop pioneering innovations for a sustainable, bio-based economy. The Hydrogen Technologies FSF drives the practical implementation of hydrogen-based technology, thus making a decisive contribution to the necessary transformation of the

energy sector and industry into a sustainable means of value creation. Within the Resource Efficiency and Climate Technologies FSF, Fraunhofer experts are working on solutions for developing sustainable economic systems such as green economy, circular economy and bioeconomy systems that will result in a far-reaching process of change for society and business.

In order to meet its environmental responsibility to the fullest extent, the Fraunhofer-Gesellschaft also established an internal climate action project (**"Fraunhofer KlimaAktiv"**) in 2020 to measure the organization's CO₂ equivalent emissions. The goal of this project is to conduct a preliminary survey of Fraunhofer-Gesellschaft greenhouse gas emissions and identify suitable starting points for reducing these. The project conducted extensive surveys to collect data and interviews with employees and the managers from various institutes and locations. The purpose was to gain insights into measures for reducing energy consumption and CO₂ emissions that have either already been implemented, have been proposed or are planned for implementation in the future. It also identified initial approaches to help the organization achieve carbon neutrality through measures for increasing energy efficiency, such as optimizing facilities and adopting energy-saving lighting technology, waste-heat utilization, increasing the levels of energy generated by Fraunhofer itself and ensuring 100% of supplied electricity is generated from renewable sources. Reducing business trips by air will also play an important role in this context (see the section **"Resources"**). Thanks to the project it is now possible for Fraunhofer to assess and significantly increase its contribution to the political goal of achieving carbon neutrality through its research activities. Core results from the project are currently being incorporated into a climate strategy for Fraunhofer, to be pursued as part of the Fraunhofer goal to achieve climate-neutral status by 2030. The project results and calculated statistics will be published along with the next corporate responsibility progress report in 2021.

Funded by the German Federal Ministry for Economic Affairs and Energy, the **"LamA – Charging at Work"** research and infrastructure project on electromobility continues to make progress. Almost half of the almost 500 charging points planned have already been installed (www.lama.zone). Depending on location, the charging points are available for various user groups and can be used by company vehicles,

private cars belonging to Fraunhofer employees and by third parties. In this way, Fraunhofer is making a major contribution to climate-friendly mobility in Germany.

In 2020, the **Fraunhofer Zukunftsstiftung (Fraunhofer Future Foundation)** also realigned its focus on projects that aim to make an impact in the area of sustainability. Funding from the foundation is restricted to projects that make a substantial contribution towards achievement of the United Nations' Sustainable Development Goals (SDGs). With an annual funding volume of €5 million, the focus in the future will be on generating value based on ethical principles with the aim of creating a tangible impact on society and the economy. The project portfolio is expected to deliver direct returns for the foundation and also establish a basis for their fundraising activities. For the first time, research projects aimed solely at contributing to the common good will also be eligible for funding.

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 of this international network in December 2020.

Research on sustainability management

Since the BMBF-funded research project LeNa – “Sustainability management in non-university research organizations” ended in 2016, and even before, Fraunhofer has continuously made progress on implementing sustainability principles. A major result of this collaboration was the creation of a guide to sustainability management in non-university research institutes. The portfolio strategy set out in this document provides a multi-step sustainability management framework, entitled the LeNa process, to help organizations integrate sustainable processes into research. While major changes have already been initiated in the area of infrastructure processes, it has been made clear that further research is needed in the area of science and research in particular. Due to a lack of methodology, impact evaluation and practical examples, it is proving difficult for researchers to implement the principle of **“Socially responsible research”** in their day-to-day research. Together with the Helmholtz Association, Leibniz Association and Max Planck Society, in 2020 the Fraunhofer-Gesellschaft worked on a proposal for an ongoing BMBF project aimed at systematically researching the conditions necessary for integrating sustainability into research and embedding it as part of operations as well as the impact of modified research processes on solutions to major societal challenges. The LeNa Shape project is due to commence in 2021 and aims to deliver essential insights and assistance for further integrating sustainability into research organizations.

Employees

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

At year-end 2020, Fraunhofer had 29,069 employees, 20,701 of whom were research, technical or administrative staff (RTA staff), 7827 students and 541 trainees. These employee figures substantiate the goal discussed between Fraunhofer and funding agencies at the beginning of the crisis in relation to retaining its staff levels and expertise. They also demonstrate that Fraunhofer can remain operational at full capacity even under changed circumstances.

The project **New Work@Fraunhofer** has been running since 2018 with the aim of creating a flexible, cooperative, participatory and customer-focused working and research environment that enables employees to work autonomously. The project was kicked off with an online survey involving 1500 employees and 500 managers and a questionnaire with input from all heads of institutes, HR managers, heads of administration and employee council chairs. The project used benchmarking data for companies and research units both within Germany and abroad to supplement the survey results. This formed a basis for establishing priority areas for the development of new models for work at Fraunhofer.

The four core “New Work” approaches adopted were:

- **Work structure** (working at flexible times and at different locations)
- **Organization** (developing and refining agile approaches and customer-oriented, cooperative forms of organization)
- **Management and self-organization** (new management concepts and transferring responsibility)
- **Cooperation** (creating meaningful self-organizing networks of knowledge and people)

These approaches are being piloted at three Fraunhofer Institutes and one Fraunhofer Cluster of Excellence.

Conclusions drawn at the project's pilot stage have been positive. The results confirmed that introducing more flexible working models can increase the attractiveness of Fraunhofer as an employer and enhance its perception as a modern partner for customers. The pilot has resulted in the development of practice-based approaches, which will now be transferred back to the institutes through heads of institutes and administration and HR managers. By early 2021 alone, over 30 institutes were already using the starter modules TAKE OFF, SYSTEMATIZE and DEVELOP to prepare for the rollout of “New Work” approaches. The TAKE OFF module evaluates

and takes into account experiences of working during the coronavirus pandemic. The SYSTEMATIZE module focuses on implementing opportunities for flexible work with respect to time and location, as well as related legal aspects. The topics of management, agility and cooperation inform the DEVELOP module of the project.

The coronavirus pandemic brought about an extraordinary working situation and unprecedented challenges for Fraunhofer Institutes and headquarters that went beyond the scope of the planned “New Work” model rollout. With the large-scale introduction of the work-from-home model, virtual and digital work formats now define everyday life and have made the need for modern formats of teamwork more urgent than ever before. Taking the current crisis as a starting point, Fraunhofer has developed a broad range of work models and guidelines to aid and support institutes as they implement the “new normal” in the workplace.

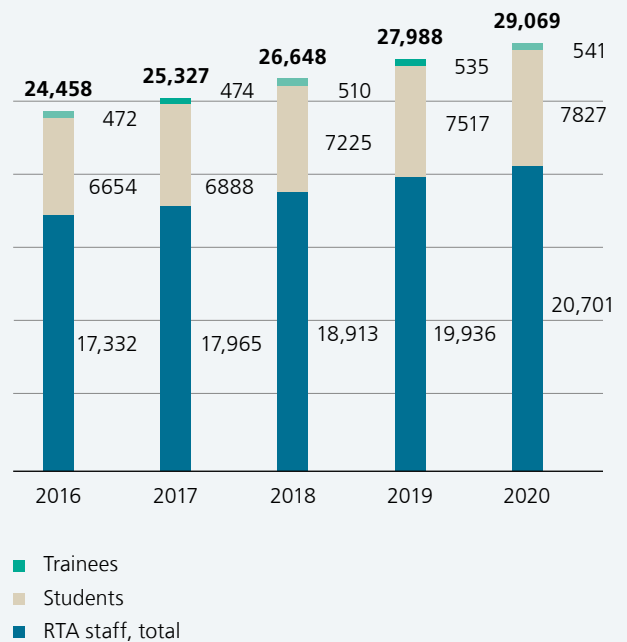
In 2020, the traditional employee performance review was again replaced with a more comprehensive **development discussion**. Another important milestone in terms of supporting development planning was extending performance reviews to trainees and to students in our dual study program.

On January 1, 2020, Fraunhofer introduced the obligatory **“Doctorate with Fraunhofer”** code of conduct. This was developed as part of a broad discussion with PhD students, supervisors, head of institutions and internal committees such as the Scientific and Technical Council and the Central Works Council. The code of conduct constitutes a binding quality standard for doctoral supervision at Fraunhofer to ensure a quality-assured framework for doctoral supervision and thus for preserving and enhancing scientific expertise at Fraunhofer. The code of conduct is underpinned by a qualification agreement issued by a Fraunhofer Institute, which sets out the main conditions for the respective doctoral project. To ensure compliance with the code of conduct, Fraunhofer identified key action areas in 2020 and supported participants through a wide range of workshops, opportunities for exchanging experiences and helpful guidelines.

From mid-March of 2020, all HR events and workshops and other important events took place on virtual platforms as a result of the **pandemic**. By working on concepts with our network of external trainers at short notice, we were able to successfully offer an extensive number of online seminars. Additionally, from mid-March onwards, employees were given access to a new information section on “Remote working” on the Fraunhofer intranet. It includes information on legal aspects, virtual tools for working with others, general guidelines on working remotely as well as tips for managers addressing specific management issues in this challenging situation.

Employees

(number at year-end)



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.

A major study on work culture conducted within Fraunhofer found that gender bias can have a negative effect on equal opportunities. **Unconscious bias** influences behavior towards others and decision-making – especially in the recruitment and selection of employees and managers, but also in terms of our daily interaction in the workplace. The topic of unconscious bias received major focus in 2020 due to its high level of pertinence. The organization implemented a range of measures focusing on the topic, such as a press campaign in Quersumme, the newspaper for Fraunhofer-Gesellschaft

employees, workshops for employees and management as well as the development of guidelines promoting gender equity in the selection of staff and managers.

Financial support is available to Fraunhofer Institutes for initiating and implementing measures to promote diversity as part of an organization-wide **diversity program**. In 2020, 23 institutes submitted a total of 27 funding applications. For all areas of funded research, funding was made available for various measures to promote general conditions and training courses, for instance, diversity training, a series of workshops on unconscious bias and a mentoring program within each institute. Against the backdrop of the pandemic, for the first time we also received applications for childcare provision for employees working remotely.

At the reporting date, **people with disabilities** accounted for 2.8 percent of the Fraunhofer workforce (2019: 3.0 percent). As regards the issue of inclusion, the focus of activities in 2020 was on further consolidating the diversity funding program at Fraunhofer. In 2020, the organization funded an onboarding package for blind or visually impaired people for using

“Unconscious bias at Fraunhofer” strategy

	Measures	Commencement	Target group
Awareness-raising	Educational films and surveys Applying for and conducting research projects Publications Speaking roles at conferences and membership of professional associations	03/2020	Institute and administration management Managers Employees Authorized representatives HR development
Sensitivity training	Training courses Online unconscious bias (UB) workshops Consultation and providing diversity and UB training	09/2020 01/2020	
Standardization	Optimizing HR processes Developing standards Rollout to institutes	09/2020 10/2020 2021	Institute management Heads of administration Managers Personnel selection

Microsoft Teams and Microsoft 365. It also funded a guide for sighted people informing them of what they should be aware of when working together with blind or visually impaired people. The topic of inclusion will also be revisited as part of activities undertaken to reduce unconscious bias.

Thanks to a cross-institute framework contract with the **pme Familienservice (a family service group)**, all Fraunhofer-Gesellschaft employees had access to the entire range of digital event services offered by the pme Familienservice in 2020. The pme Akademie offers online presentations and seminars on the subjects of childcare, care, support and mental health.

Due to the COVID-19 pandemic, the award process for the **Fraunhofer FamilienLogo**, which was due take place in 2020, was postponed until 2021. Institutes that had already been awarded the logo were able to extend its validity. Institutes interested in attaining the award for the first time can avail of a consultation to help them prepare for the 2021 certification process.

The recruitment board's **Executive Search Team** has drawn up a candidate sourcing process with the goal of further integrating this process into ongoing and future appointment procedures. Our two female employees are currently using this process for 13 appointment procedures. By searching in a targeted manner and directly approaching suitable female candidates, they have been able to reach passive candidates in particular and make them aware of current job advertisements. This approach has already enabled Fraunhofer to significantly increase the number of applications from top female candidates within Germany and internationally.

We have further consolidated our pool of **internal female candidates for a W2/W3 professorship**. Combining the selection procedure with the TALENTA *excellence* program provided meaningful results; the fall 2020 selection round saw two additional female candidates accepted from the W2/W3 pool. A total of four female scientists are currently negotiating their appointment at Fraunhofer with universities. Two of these candidates have decided to continue their career in science, which represents a successful example of knowledge transfer for Fraunhofer.

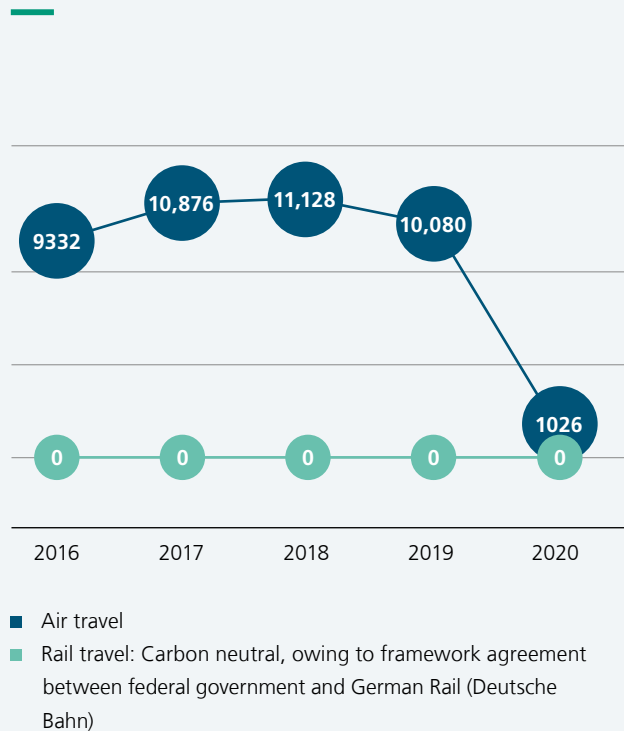
In addition to the above, Fraunhofer aims to increase the ratio of women on its **scientific advisory boards and supervisory boards**. The number of women on advisory boards equated to 22.3 percent at the end of 2020 (2019: 19.5 percent). In the Fraunhofer Senate – the organization's highest steering committee – women currently account for 47 percent of the elected members (2019: 39 percent).

Resources – mobility and waste management

Domestic and international business trips by employees were significantly reduced due to the coronavirus pandemic. Many events and trade fairs were canceled and took place virtually instead. The number of business trips, in particular business flights, plunged as a result, as demonstrated by the comparably low CO₂ emissions from air travel, which amounted to only 1026 tons in 2020. This is equivalent to a decrease of 90 percent. There was also a sharp fall in trips made by train, with a decrease of around 80 percent to just 8 million passenger kilometers in 2020. According to the framework agreement between the federal government and German Rail (Deutsche Bahn), rail travel is carbon neutral. Therefore, we cannot report a change in CO₂ emissions for rail travel. For the first time, Fraunhofer will offset carbon emissions for air travel in 2020, as set out in a 2019 resolution. The corresponding offsetting tender is in preparation and anticipated to be ready in early 2021.

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 for 2019 only. In 2019, the Fraunhofer Institutes generated 5396 metric tons of non-hazardous waste and 638 metric tons of hazardous waste. This amounts to a reduction of 236 metric tons in non-hazardous waste and 180 metric tons in hazardous waste compared to 2018. The reduction in non-hazardous waste is a result of the institutes' efforts. The differences in totals for hazardous waste can largely be explained by the fact that some projects generate more waste than others, and the amount of waste cannot always be assessed directly.

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



Volume of waste produced by Fraunhofer Institutes, in metric tons



Risks and outlook

Risk management and risks

The Fraunhofer-Gesellschaft has been negatively affected by the coronavirus crisis, which has resulted in a deterioration of the organization's risk situation. Overall, however, there is no lasting threat to the Fraunhofer-Gesellschaft.

Since the scope of the effects of coronavirus cannot be accurately predicted, due to the growing number of mutations as well as other factors, the Fraunhofer Executive Board has developed a range of scenarios with related measures to enable the organization to respond rapidly to future developments. For instance, an increased allowance was approved by the funding agency to enable Fraunhofer to retain the expertise and capacities of its staff – so important for tackling the crisis in Germany and Europe. The coronavirus crisis management team is closely monitoring and analyzing the evolving situation so it can adapt measures in response to changes on an ongoing basis.

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.

The Fraunhofer **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 the business success of Fraunhofer 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 has been accepted by Fraunhofer-Gesellschaft's auditors as being adequate and suitable for this 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 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.

Fraunhofer classifies risks according to an organization-specific model which forms the basis for the annual risk assessment that 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.

The COVID-19 pandemic is likely to have temporary effects on certain areas of the **research portfolio**. In anticipation of this, Fraunhofer is intensifying current activities in relation to strategic portfolio management.

Indirect financial risks may arise for the Fraunhofer-Gesellschaft from contingent liabilities and operational risks in connection with the **legally independent international Fraunhofer affiliates**. For instance, one such international affiliate, Fraunhofer USA, Inc., is currently engaged in legal action with a company in the United States.

In the context of **financial risks**, containing risks that might compromise the organization's access to research funding or its solvency is key.

Base funding by the federal and state governments is **one of three main sources of finance for the Fraunhofer-Gesellschaft**. It is used principally as a means of driving qualitative growth through the establishment of new fields and topics of research. As an applied research organization, revenue from industry is another of the three main sources of finance that has experienced a slump due to the COVID-19 pandemic. The German Federal Ministry of Education and Research has granted an additional allowance to compensate for this loss in revenue so that Fraunhofer can retain the expertise and capacities of its staff in combating the crisis in Germany and Europe.

In order to maintain the share of base funding in the funding mix in the long term, Fraunhofer proactively manages its growth and lobbies state and federal governments for institutional funding in keeping with its mission and in proportion to its performance along with working conditions appropriate to the research sector. The current management statutes enable Fraunhofer to act flexibly, efficiently and autonomously. If this were to be curtailed, it would limit the organization's **liquidity**, restrict its ability to make provision for risks and hamper 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 control 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 tangible and intangible resources needed to successfully carry out research activities.

Employees are our key success factor when it comes to successful research. Within the context of the current pandemic, Fraunhofer has undertaken a comprehensive range of measures to maintain our business processes and protect employees and customers against infection. These measures are monitored on an ongoing basis and adapted according to the latest developments.

The ability to protect **intellectual property (IP)** by means of laws, directives and other enforceable rules plays a crucial role in the success of Fraunhofer and is a 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.

Modern, high-performance IT systems help to streamline business processes in research management. Fraunhofer has prepared for any organizational challenges that could arise during the migration to the **new ERP software system** through a temporary increase of technical department staff and structured project management and control including regular monitoring of project planning.

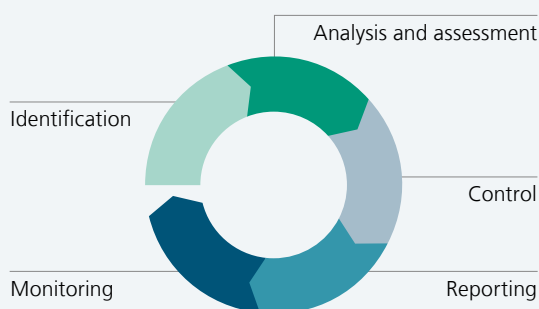
Fraunhofer is exposed to **capital market risk** insofar as it invests part of its capital and reserves with a view to earning a return. The financial investments of the Fraunhofer-Gesellschaft are managed by a special investment fund under German investment law and limited partners interests. The organization 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 general terms and conditions of business and in its standard contracts, by engaging specialized legal experts, and through a multi-tier approval process based on competent legal advice.

The application of strict IT security measures is of fundamental importance to the ongoing existence of a knowledge-based research organization. Fraunhofer is reducing the increase in potential **information security** risks through targeted measures that are continuously updated and documented in an authoritative information security manual.

Cyclic risk management process



How Fraunhofer classifies risks

Main areas

Business model

Specific risk types

State aid rules
Non-profit status, taxation
IP exploitation, spin-offs
Corporate strategy, portfolio management
International activities

Finances

Base funding
Public-sector revenue
Industrial revenue
Operating expenses/Capital expenditure/Construction
Liquidity, pre-financing, other financial risks

Resources

Employees
IP, know-how
Infrastructure
Financial assets, reserves
Reputation, brand

Business operations

Delivery of service, contractual risks
Legal risks
Information security
Governance, internal control system

Outlook

For 2021, the end of the first quarter is showing positive signs for Fraunhofer. Fraunhofer anticipates that it will be able to continue to retain its staff levels and expertise if adequately supported by the funding agencies, as planned. However, achieving profit targets remains subject to risk, since the continuing lockdown measures and the effects of same are expected to negatively affect economic development. Nevertheless, Fraunhofer is confident that its R&D portfolio will be in high demand by the business community due to its wide-ranging expertise on crisis management and new acquisitions. Even as the crisis continues, the Fraunhofer funding model offers a solid foundation.

As part of the scheduled **SAP integration**, Fraunhofer has completed a number of essential steps. The coronavirus pandemic necessitated a rapid, ad-hoc reorganization of daily teamwork processes, with all meetings and events transferred to digital channels. It involved setting up a complex system comprising 40 standalone SAP applications and 20 cloud solutions, each with its own roles and permissions, in order to test basic functionality and to plan and start training employees to use the system. Against the backdrop of potentially similar challenges in 2021, it is necessary to ensure that Fraunhofer remains capable of functioning during a crisis and can make its expertise and capabilities available for customers and partners at all times, without limitations and to the fullest extent. For this reason, following user acceptance testing at the end of November 2020, the Executive Board decided to postpone SAP integration for one year, until early 2022.

Fraunhofer is planning a new central transfer structure through its **lead-market-oriented alliances**. These alliances are cooperative technology transfer platforms used by multiple Fraunhofer Institutes for lead markets, i.e. sectors that are of particular relevance in driving innovation across Germany and Europe. An alliance functions as a one-stop shop that provides industry customers with optimum access to cross-institute research services and system solutions offered by a range of institutes. Lead market projects targeting the four areas of plant, mechanical and vehicle engineering, the construction industry, the energy industry and the mobility sector are set to launch in 2021. With the pandemic having accelerated the growth of the digital economy and healthcare sector in particular, Fraunhofer will also focus on developing these areas as lead markets in 2021. It plans to focus on development of the chemical industry and food industry as lead markets at a later stage.

The **new group structure** aims to fulfill the demands of the portfolio structuring process internally and the enhanced presentation of its expertise externally, thus ensuring better synergies at all levels. As of 2021, the Fraunhofer Institutes

will be structured into nine groups, where each group will be responsible for coordinating its internal affairs and managing external cooperation. These groups are as follows:

- Energy Technologies and Climate Protection
- Health
- ICT Group
- Innovation Research
- Light & Surfaces
- Materials and Components
- Microelectronics
- Production
- Resource Technologies and Bioeconomy

In 2021, Fraunhofer will continue to implement the structural optimization measures initiated by the Fraunhofer Future Commission. Optimization measures include the focused development of expertise through the established groups, vocational training for lead-market-oriented alliances (supported at corporate level) and the leading initiative in the form of seven Fraunhofer Strategic Research Fields (FSF). In terms of the above, Fraunhofer is very well positioned for any dynamic adjustments in the future.

Prof. Dr. Ralf B. Wehrspohn, Executive Vice President, Technology Marketing and Business Models, will leave the Fraunhofer-Gesellschaft at his own request and will cease his role as member of the Executive Board on March 31, 2021. The Executive Board and the Presidential Council would like to thank Professor Wehrspohn for all his work.

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 2020.

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

Executive Board

Prof. Dr.-Ing. Reimund Neugebauer

Prof. Dr. rer. publ. ass. iur. Alexander Kurz

Dipl.-Kfm. Andreas Meuer

Prof. Dr. rer. nat. Ralf B. Wehrspohn

#WeKnowHow

Report of the Senate on the financial year 2020



Prof. Dr.-Ing. Heinz Jörg Fuhrmann

The year 2020 was characterized by major challenges for the Fraunhofer-Gesellschaft, not least due to the SARS-CoV-2 pandemic. These ranged first and foremost from a significant drop in industry research contracts from sectors affected by the crisis, to changes in everyday life for work and research. Thanks to the tremendous input of all employees and support from the German federal government and the Federal Ministry of Education and Research, we were able to successfully overcome these challenges.

A total business volume of approximately €2.8 billion ensured a stable performance and the retention of expertise. The Fraunhofer-Gesellschaft was therefore able to continue its role as a driving force for innovation and value creation within industry and society to the fullest extent. This can be demonstrated by new research initiatives for technology-based advances for tackling the pandemic through the Fraunhofer-Gesellschaft program for combating coronavirus and the Fraunhofer innovation program for driving innovation within industry. It also includes initiatives aimed at retaining staff levels and further developing expertise.

Notwithstanding the necessary precautionary measures for protecting health and the related organizational challenges, the Fraunhofer-Gesellschaft was able to continue to advance its forward-thinking approach to research in a systematic way. Examples of this include the successful establishment of the Fraunhofer Strategic Research Fields and Fraunhofer lead-market alliances, as well as the development of the group structure.

The Fraunhofer-Gesellschaft returned a solid balance sheet for 2020. Once again, the financial statements received an unqualified audit certificate from the appointed auditing firm.

In 2020, the Senate fulfilled the duties entrusted to it under the Statute of the Fraunhofer-Gesellschaft. It convened twice in the course of the financial year: on May 12 and on October 8. Both meetings took place online due to the SARS-CoV-2 pandemic. Resolutions were passed based on the written circulation procedure.

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

- In accordance with section 12, para. 2, item e) of the Fraunhofer Statute, the Senate assessed the 2021 business plan (key data) drawn up by the Executive Board.
- On January 1, 2021, the Senate passed a resolution to spin off the two institute locations of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME in Frankfurt and Hamburg into an independent Fraunhofer Institute for Translational Medicine and Pharmacology ITMP under the management of Prof. Dr. Dr. Gerd Geißlinger.
- The Senate unanimously proposed that the General Assembly elect Bavarian Minister-President Dr. Markus Söder as

an honorary member of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. The Executive Board had proposed that the Senate award Minister-President Dr. Markus Söder honorary membership of the Fraunhofer-Gesellschaft in recognition of his outstanding political engagement for the benefit of applied research in Bavaria and further afield, in particular in future-focused technology areas such as AI and quantum computing. The General Assembly election took place on October 9, 2020.

- The Senate followed the recommendation of the Senate committee for the appointment and reappointment of Executive Board members by reelecting Prof. Dr. rer. publ. ass. iur. Alexander Kurz to the position of Executive Vice President, Human Resources, Legal Affairs and IP Management for the period from June 1, 2021 to May 31, 2026.

The Senate would like to take this opportunity to thank the Executive Board and all employees of the Fraunhofer-Gesellschaft for their great dedication and hard work under the challenging conditions of a global pandemic during the 2020 financial year.

Prof. Dr.-Ing.

Heinz Jörg Fuhrmann

Chair of the Senate of the
Fraunhofer-Gesellschaft

Inside the Fraunhofer Senate



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Even more so in times of high volatility and strict controls do we aspire to keep driving innovation and our sights firmly fixed on the future. We have the opportunity and the responsibility today to usher in a new era of aviation – as a core element of sustainable mobility.”

Grazia Vittadini

Airbus chief technology officer & member of the Airbus executive committee

Grazia Vittadini

Grazia Vittadini was appointed to the board of Airbus as chief technology officer and as a member of the Airbus executive committee in 2018. From January 2017, she was executive vice president head of engineering and a member of the Airbus defence and space executive committee. For many of the positions she has held, she has been the first ever woman to occupy the role. For many years, Airbus has been committed to enhancing diversity and inclusion in aerospace companies and mechanical engineering. There has also been a steady increase in the number of women employees at Airbus itself, where the current figure lies at 18 percent.

Airbus is a leading global company in the field of aerospace and aerospace-related services. In the 2019 financial year, the Airbus consortium had around 135,000 employees. Airbus is the European market leader for the production of tanker, combat, transport and special mission military aircraft, and is one of the world's largest space travel companies. As a leading manufacturer of commercial aircraft on a global level, the corporation also aspires to be a pioneer in technology that advances the shift from fossil fuels and drives the decarbonization of air travel. Airbus aims to bring a fully CO₂-neutral passenger aircraft onto the market by 2035.

The headquarters of Grazia Vittadini's transnational and globally operating team is located in Germany. Almost half of all employees in the entire German aerospace industry work at Airbus' 27 locations in Germany. In addition to commercial aircraft and helicopter production, Airbus is engaged in developing advanced technology and custom products in Germany for enhancing national security, such as military helicopters, satellite programs for secure military communication and the Eurofighter combat aircraft.

Grazia Vittadini has always led international teams at various locations, and was chief engineer for the wing high-lift devices of the A380 in Bremen. Born in Milan, she began her professional career on the Italian side of the Eurofighter Consortium. She joined Airbus Operations in Germany in 2002 and quickly rose to management positions such as chief engineer and head of corporate auditing. She graduated in aeronautical engineering with a specialization in aerodynamics from the Polytechnic University of Milan (Politecnico di Milano).

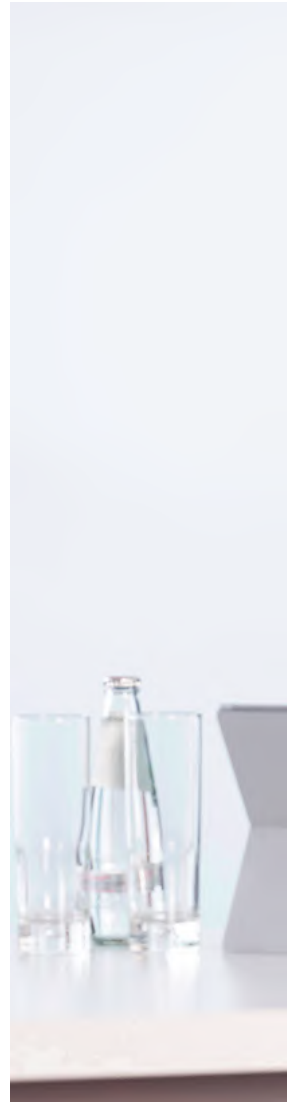
Dr. Karl Tragl

Dr. Karl Tragl was spokesman of the executive board of the Diehl Group until 2020 and is still active with the consortium in a consultancy role. He comes with an extensive entrepreneurial track record in various industry sectors combined with international experience with modern manufacturing systems and innovative methods used in the fields of Industrie 4.0, automation engineering and 3D printing.

Dr. Tragl graduated in physics from the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and subsequently completed a doctorate at the German Aerospace Center (DLR) in Oberpfaffenhofen. He began his career in 1991 at what would later become Siemens Management Consulting, where he worked as a management consultant for restructuring, growth and innovation projects. Subsequently, he took over global business management for Siemens' frequency converter division, based in England.

In 2000, Dr. Tragl moved to the mechanical engineering firm Bosch Rexroth AG where he worked for 16 years and occupied various management positions before taking overall charge of the company as CEO in 2010. He then worked in the USA as Group CEO of the Aluminum Company of America. After the company was spun off into two independent, listed companies, he went on to head up the engineered products and solutions division of Arconic.

More recently, he held the role of spokesman of the executive board of the Diehl Group between 2018 and 2020. Diehl is a global family-run company with headquarters in Nuremberg and 60 subsidiaries and joint ventures worldwide. The Diehl Group is structured into the business units Metall, Controls, Defence, Aviation and Metering, has around 17,500 employees and generated a turnover of €3.6 billion in 2019.





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We need to actively approach change within industry and society with courage and curiosity. Openness on a global scale, diversification, security and sustainability are essential values here. The key to our future is technology-based advances in digitalization, artificial intelligence and new materials."

Dr. Karl Tragl
Former spokesman
of the executive board
of the Diehl Group



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Creating value in an innovative, sustainable way generates attractive employment opportunities and safeguards the prosperity of our society. Industry, science and politics have a shared responsibility to strive for a positive future. Cooperation and competition are not mutually exclusive – both are needed for successful collaboration.”

Dr.-Ing. Anna-Katharina Wittenstein

Member of the management board of Wittenstein SE

Dr.-Ing. Anna-Katharina Wittenstein

Dr.-Ing. Anna-Katharina Wittenstein has been a member of the management board of Wittenstein SE since 2016.

The family-owned company is a high-tech enterprise whose core competence lies in the field of mechatronic drive systems. From its headquarters in Igersheim and across its 25 locations in more than 45 countries, the company is focused on producing customized systems and solutions for highly dynamic motion, ultra-precise positioning and intelligent networking. The company's products are used in robots, tool machinery, medical engineering, aerospace and even in Formula 1 racing. A team of employees from Wittenstein SE who created a new type of gearbox were among the finalists for the German Future Prize in 2018.

Born in Würzburg, Anna-Katharina Wittenstein studied business administration at the Julius-Maximilians-Universität of Würzburg (JMU) and at the University of Mannheim. From 2002 to 2006, she worked initially as a consultant and later was a research fellow at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA in Stuttgart. After completing her doctorate at the University of Stuttgart, she joined the family firm as operational managing director and oversaw the development of a manufacturing facility for Wittenstein SE in Switzerland. A later role as Chair of the Board of a company subsidiary in the USA prepared her for an Executive Board role at the family firm back in Germany. The family business has since passed on to the next generation, with her father Dr. Manfred Wittenstein now chair of the supervisory board.

Anna-Katharina Wittenstein has been a member of the board of trustees at the Fraunhofer Institute for Manufacturing Engineering and Automation IPA since 2018. She is also a member of the Innovation Dialog advisory board for facilitating exchange between the German federal government, industry and science.

Bernard Meyer

Bernard Meyer is managing director of Meyer Werft. Headquartered in Papenburg, Lower Saxony, the company made a name for itself from the mid-1980s onwards by building luxury passenger ships. It is now a global market leader in the sector. Founded in 1795 by Willm Rolf Meyer, the company has been in the Meyer family for six generations, with Bernard Meyer currently CEO.

One of the largest employers in the Emsland/Ostfriesland region, Meyer Werft builds cruise ships, ferries and gasoline tankers for customers all over the world. It was Bernard Meyer himself who moved the company in the direction of cruise ship building in the 1980s. Since then, more than 50 of these vast ocean liners have departed the firm's covered dry dock – one of the world's largest – in Papenburg.

Given the growing relevance of sustainability and climate protection in the tourism sector and the world's oceans, in 2018 Meyer Werft built AIDAnova, the world's cleanest cruise ship. This is the first cruise ship in the world to be powered by liquefied natural gas (LNG). LNG largely eliminates ship exhaust particulate matter and sulfur oxide emissions, and significantly reduces nitrogen oxide and carbon dioxide emissions.

Bernard Meyer was born in Papenburg in 1948. After studying shipbuilding engineering in Hannover and Hamburg, he joined the family firm in 1973, taking over its management in 1982. With the acquisition of the German company Neptun Werft in 1997 and the Finnish company Werft Meyer Turku in 2014, the group expanded in terms of size and international recognition. Meyer is a member of the presidential council of the German Shipbuilding and Ocean Industries Association (VSM), which represents the economic interests of the German maritime industry. He is also active on an international level and has been on the board of SEA Europe, the Shipyards' & Maritime Equipment Association of Europe, for many years. 2009 saw Meyer awarded a special honor – the Werner von Siemens Ring – which is one of the highest awards for science and technology in Germany.



A portrait of Bernard Meyer, an older man with grey hair and glasses, wearing a dark blue suit and tie. He is looking slightly to the left. The background is a bright, out-of-focus window.

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Our goal is to develop and build sustainable, climate-neutral cruise ships. By using a low-emission LNG drive system, we have already made some new advances. Thanks to our research into fuel cells, the use of regenerative methanol as fuel and other technology, we are moving ever closer to our goal. With a lot of entrepreneurial spirit, know-how and our experience, we are confident we will get there.”

Bernard Meyer
Managing director of
Meyer Werft



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Research and innovation can help us – now in particular, with vaccinations, treatment and strategies for containing the coronavirus pandemic. This gives us the reasonable hope that we can protect more and more people, and continue to learn better ways of living with the virus. The successful results of the close tie between research excellence and transfer to product development are clearly visible here. This shows us that research can help us overcome societal challenges.”

Bärbel Bas
Deputy chair of the SPD
parliamentary group

Bärbel Bas



Bärbel Bas has been a member of the German Bundestag since October 2009. In her role of deputy chair of the SPD parliamentary group, she is responsible for health, education and research and for dealing with petitions. She is also a member of the study commission “Vocational Training in the Digital Work Environment.” As a member of the Bundestag, she represents the constituency of Duisburg I.

Bärbel Bas was born in 1968 and grew up with five siblings in Duisburg. After obtaining her secondary school diploma, she began an apprenticeship at the Duisburg Transport Company (Duisburger Verkehrsgesellschaft – DVG). During this time she was elected representative for young people and trainees, and campaigned for improved training conditions. A believer in life-long learning, she continued to gain qualifications in a number of areas, and trained as a health insurance business administrator and later as a human resources economist. She held a number of management positions at health insurance firm BKK futur, now merged with the BKK VBU.

Bärbel Bas joined the SPD in 1988, and was later chair of the Duisburg wing of the Working Group of Young Socialists in the SPD (Jusos) for nine years. From 1994 to 2002 she was a member of the City Council of Duisburg, where her main areas of focus were young people and health. In the 2009 federal election, she was elected for her constituency to the 17th German Bundestag. She served as chief whip of the SPD parliamentary group from 2013 to 2019, and since 2019 acts as deputy chair of the SPD parliamentary group with responsibility for health, education and research and for dealing with petitions.



Dr. Markus Söder
Bavarian Minister-President

Dr. Markus Söder, Honorary Member of the Fraunhofer-Gesellschaft

At its annual meeting in fall 2020, which took place virtually, the Fraunhofer General Assembly awarded Dr. Markus Söder honorary membership of the Fraunhofer-Gesellschaft in recognition of his outstanding political engagement for the benefit of research in Bavaria and further afield.

Born in Nuremberg, Söder has been Minister-President of Bavaria since March 2018 and leader of the Christian Social Union party in Bavaria (CSU) since January 2019. In 2018, Söder introduced the “High-tech Agenda,” a technology campaign aimed at promoting research in Bavaria. The initiative was focused on advancing the development of modern technology and its practical implementation. His “High-tech Agenda Plus” initiative builds on these measures and has made a number of proposals, such as working with the Munich Quantum Valley alliance to create a world-class technology park.

Markus Söder joined the CSU at the age of 16. After completing secondary school and military service, he studied law at the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), with a scholarship from the Konrad Adenauer Foundation. Söder worked as a research assistant at the department of constitutional, administrative and church law after finishing his studies, and later completed a traineeship at Bayerischer Rundfunk, a public-service television and radio network. Söder has been a member of the state parliament of Bavaria since 1994, and was for many years regional chairman of Young Union Bavaria and a member of the CSU Presidential Council. From 2003 to 2007 he was secretary general of the CSU party; between 2007 and 2018 he held various ministerial posts in the state government. In March 2018, Markus Söder was elected Minister-President by the Bavarian state parliament and was confirmed in office following the October 2018 state elections.

He is married with four children and lives in Nuremberg and Munich.



Fraunhofer and Bavaria form a great alliance, one that we want to continue to strengthen in future. The goal is to use modern technology to improve the world we live in, and to be open to change. We must face the challenges of today and tomorrow head-on, and demonstrate the innovative capability of both Bavaria and Germany as a whole through essential technologies of the future such as artificial intelligence, digitalization, quantum technologies and mobility.”

Resilience through health
research: cost-aware precision
medicine for the benefit of
patients.





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Resilience in complex systems – a practical application strategy from Fraunhofer



*Technical infrastructures
must be able to withstand
even severe shocks.*

With the COVID-19 pandemic, 2020 focused public attention on the topic of resilience. Government, industry, research and society are holding intensive discussions on how to determine the resilience of organizations, infrastructures and other complex technical and socio-technical systems and in particular, what measures can be adopted to strengthen them. For example, what attributes determine whether a company or an entire value chain will become non-operational as a result of even minor disruptions or will have the ability to absorb even severe shocks? What organizational, technical or staffing measures can decision-makers use to ensure that the systems recover quickly or even emerge stronger after future crises?

Our understanding of resilience

Resilience is the ability of technical or socio-technical systems to absorb shocks and disruptive events and maintain or quickly restore core functionalities as well as to learn from experience and adapt to changing environmental conditions.

Complexity requires system expertise

For many years, numerous Fraunhofer Institutes have been using a variety of methodological approaches to research concepts and solutions that can help to increase resilience. Even as far back as 2014, a joint project with acatech – the German National Academy of Science and Engineering produced recommendations for the government as regards means and measures that could be used to come closer to achieving the goal of a more resilient economy and society. In this context, the Fraunhofer-Gesellschaft combines forms of expertise from across a broad spectrum in order to drive progress in the research field of resilience using a wide variety of technological, sociological and economic methods. With its unique expertise and experience in applied research, Fraunhofer aims to help deepen our understanding of the factors that make systems resilient and adaptable.

Our aim thereby is to present solutions that can help decision-makers in government and industry to be as well prepared as possible for future shocks and crises. Using concrete project examples and initiatives, we make it clear that even today, versatile cooperation between the various scientific and technical areas of expertise forms the basis for a more resilient society, government and industry.

The new imperative of resilience

Even irrespective of the challenges presented by COVID-19, it will become increasingly important in the coming years to develop a deeper understanding of the resilience of our systems and invest in measures for improving resilience. It is likely that various global change processes, such as climate change, the energy and transport transitions or even geopolitical dynamics, will have direct and often disruptive effects on industry and society. At the same time, industrial and production systems are becoming more and more complex as a result of digitalization and this can lead to new vulnerabilities to shock. Cascade effects can turn what was just a local disruption into a systemic challenge.

An informed, holistic understanding of the resilience properties of our systems, combined with strategic funding for increasing resilience, can help to meet these complex challenges and be successful over the long term, even in uncertain times. In no way does an increase in resilience necessarily mean a loss of efficiency. Investing wisely in strengthening systemic resilience can even help to increase efficiency in the long term and from an industrial point of view, even give a particular location advantages over competitors in the long term. Particularly when it comes to shaping central transformation processes, such as decarbonization, the energy transition or digitalization, which undoubtedly involve unexpected disruptions and unpredictable dynamics, a high degree of resilience is a key success factor.

Three core abilities are crucial for resilience

In accordance with the Fraunhofer mission statement, our aspiration is to clearly define the framework conditions we set out for applying our approach to resilience. Our understanding of resilience is therefore based on the foundations described below.

In a complex world shaped by uncertainty, not all risks can be identified at an early stage, which means that shocks are inevitable. Resilient systems, however, can absorb such events, and maintain or quickly restore their core functionalities in the process. Furthermore, they learn from experience and adapt to changing environmental conditions. This applies both for technical systems, such as infrastructures, and for socio-technical systems, e.g. organizations and supply chains. In light of that, our approach focuses on three core abilities:

1. Resilient systems have the ability to respond with speed and flexibility in very different shock situations in order to minimize the effects. Regardless of the cause of a disruption or shock, there are adequate redundancies available to compensate for breakdowns and prevent cascade effects.

2. Resilient systems also have the resources to detect subtle but gradually mounting stress factors and strains at an early stage and proactively introduce countermeasures. For this to succeed, we believe that a combination of technical, organizational and economic methods are always required. This will not only give resilient systems the ability to withstand unexpected shocks, but also to continually adapt to a changing system environment.
3. In our opinion, systemic resilience involves more than the ability to “bounce back” after a shock event. In fact, resilient systems have the dynamic ability to act proactively before, during and after a shock event, to use shocks to learn how to develop continuously and if necessary, to tackle transformations successfully as well. An important prerequisite for this is to be highly innovative.

Due to the complexity of the systems involved, the strategic strengthening of these core abilities cannot be achieved using isolated individual measures. Instead, a holistic approach is required. This means that very different perspectives and forms of expertise must be combined both for the resilience analysis and for the development of measures aimed at promoting resilience based on this analysis.



Top:
With its “Anti-coronavirus” action program, Fraunhofer is providing funding to help overcome the medical crisis, in order to maintain its impact and innovative power.

Bottom:
Employees at Fraunhofer ITEM implemented a new production strategy for antibodies.

Resilience is not defined as the cementing of a state, rather as the core element of dynamic transformation processes.

Conditions for successful resilience strategies

Various consulting companies are now expanding their service portfolio to include resilience consulting. In many cases, the methods used are a thinly veiled reproduction of well-known concepts from risk management. The notorious weakness of these approaches, however, is that as a rule, particularly infrequent and serious disruptions are often not detected at an early stage and the affected systems are still largely unprepared for the most critical shocks and that very little emphasis is placed on crisis management. Such approaches also focus on safeguarding established functions of systems and provide no resources for the adaptation processes required after a crisis. Resilience strategies can bring a high level of added value in this area, but they require a fundamentally different approach.

People often underestimate the fact that the ability to increase the resilience of an organization or infrastructure requires a deep understanding of the actual system, the criticality of individual components within the system and the reciprocal dependencies of external stakeholders and other factors. Consequently, five central approaches are required when developing comprehensive resilience strategies:

1. Approaches from various disciplines in applied research must be integrated, strategically implemented and translated into suitable solutions for industry and government. While resilience models from engineering science help to improve the resilience of technical systems (e.g. infrastructures), resilience methodologies from the social sciences explore questions such as how organizations and other social systems can learn from crises and shocks and how their adaptability can be increased. In reality, we mostly deal with socio-technical systems. For example, the resilience of a company's IT system depends not only on the hardware and software used, but also at least to the same extent on the employees' expertise in handling that hardware and software. By that logic, developing holistic resilience strategies requires an integrated approach.
2. Methodological expertise on the one hand, and technological, industrial and domain-specific expertise from all industrial sectors on the other must be linked together, and existing knowledge on system expertise in resilience must be harnessed. Against the backdrop of increasingly globalized value chains and complex international regulatory framework conditions, an intensive knowledge exchange with international partners is crucial for this. To that end, Fraunhofer founded the Global Resilience Research Network together with partners from more than 20 countries worldwide in 2018.
3. Resilience must not be viewed as a static state, but rather as a characteristic of a dynamically changing system that links together flexibility, adaptability and robustness. Resilience is not therefore defined as the cementing of a state, rather as the core element of dynamic transformation processes. This enables not only successful management of unexpected crises and shocks, but also provides the basic prerequisite for proactively influencing the global dynamics and challenges of the 21st century, such as climate change, digitalization or and the energy and transport transitions.
4. The economic perspective must be taken into consideration. In particular, it is important to highlight the added value of investing in resilience measures in the medium and long-term. Here, it is important to differentiate between economically viable advancements and unprofitable measures in order to ensure that companies and government buy into these investments. For example, engineering models and simulations can show entrepreneurs how investing wisely in "preparedness" and "mitigation" significantly reduces the costs of managing a crisis situation.
5. We must present political and industrial decision-makers with strategic planning and action options for greater resilience and also provide small and medium-sized enterprises with practical tools for measuring and increasing their resilience. Technical, organizational and financial measures

that help to increase the resilience of a company must be precisely identified, quantified and implemented in a reciprocal, relational model so that decision-makers can also manage these in an operational context.

Resilience expertise at Fraunhofer

For over ten years, Fraunhofer has been conducting interdisciplinary, applied research for technologies and innovations that can make our vital systems more resilient. The institutes' expertise includes established topics, such as the protection of critical infrastructures, the resilience of production and logistics processes, decentralized energy and transport concepts for the energy transition as well as, more recently, an increased focus on digital technologies, such as the use of techniques from artificial intelligence to increase the resilience of technical systems.

As resilience is a topic that spans many different disciplines on the one hand and has such great relevance for all sectors of the economy and industry on the other, no specialist group has been established within the Fraunhofer-Gesellschaft as yet to address the topic. Thanks to the strategic amalgamation and coordination of the multifaceted forms of expertise in resilience at the Fraunhofer Institutes, we are in a position to offer a range of resilience services that are absolutely unique in Germany and can be made available for the benefit of society and industry, in line with the mission of the Fraunhofer-Gesellschaft.

The Fraunhofer Strategic Research Fields contribute to strengthening resilience in many areas of application.





Automation technologies accelerate pharmaceutical research and thus increase the pace of innovation.

A selection of applied resilience research initiatives at Fraunhofer

Read on for examples of projects and tools that various Fraunhofer teams have already launched to increase resilience.

Crisis management and resilience – Coronavirus (KResCo)

For more than a year, the COVID-19 pandemic has posed huge challenges for many areas of society. In the process, a wide range of developments, arising from varying requirements, structures, measures and effects, have been observed in different countries and industrial areas. The diverse solution strategies are examined and analyzed in more detail in the collaborative Fraunhofer project “Crisis management and resilience – Coronavirus” (KResCo). The project is part of the “Fraunhofer vs. Corona” action program, through which Fraunhofer is joining the front lines of the fight against the COVID-19 pandemic – and helping industry and society to overcome the immediate effects and future consequences.

The objective of the KResCo project is to analyze political decisions and their impact in relation to the COVID-19 pandemic. For example, the project looks at the factors that influence organizations’ ability to adapt and

innovate in crisis situations, but also at the ways in which the pandemic can act as a catalyst for digital transformation processes. Using this basis, recommendations for action are being developed for various areas of society, with the aim of providing assistance during this and any future pandemics. The results of the project have the capacity to contribute to higher levels of resilience in society, as decision-makers may develop a better understanding of the multifaceted ramifications of their decisions, and crisis management will be strengthened as a consequence. Another high-priority objective of KResCo is to develop openly accessible data for further scientific work in relation to pandemic responses.

The project is organized through the Fraunhofer Group for Innovation Research and combines different areas of expertise from the Fraunhofer Institutes for Technological Trend Analysis INT, for Systems and Innovation Research ISI and for Industrial Engineering IAO as well as the Fraunhofer Center for International Management and Knowledge Economy IMW and the Fraunhofer Information Center for Planning and Building IRB.

The Fraunhofer resilience evaluator (FReE)

Resilience is the key to enabling companies to successfully overcome crises, but it does not come about by chance: it can be strategically

planned and rendered quantifiable. That was the premise when work commenced on developing a tool specifically for small and medium-sized enterprises (SMEs) that want to approach the topic strategically. Perceiving resilience as a core characteristic of your company or the organization is the most important step in strategic planning for resilience. Using a web-based tool in the form of a structured questionnaire, SMEs can record, evaluate and visualize their current resilience status and use this information to develop concrete technical, organizational and economic measures for increasing resilience. This gives a clear view of topics relating to infrastructure and technology, organization, finances and human resources; ultimately, the interaction of all these factors provides an indication of how resilient a company is.

In the context of the “Fraunhofer vs. Corona” program, the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI developed the tool further so that it is now available for different sectors and companies of different sizes.

Restructuring and design concepts for increasing resilience in supply and production networks (Fraunhofer RESYST)

The Fraunhofer innovation program Resilient Value Creation Systems (RESYST) focuses on resilient and dynamic value creation systems with consistently high productivity and individualization. An interdisciplinary consortium consisting of 17 Fraunhofer Institutes is developing concrete design and action recommendations for both the planning process and the operating phase of resilient production and logistics systems. Resilient delivery design is a central prerequisite for fail-safe supply. For this reason, knowing how to identify, develop and structure resilience indicators is becoming a decisive competitive factor. In the RESYST project, the Fraunhofer Institutes for Material Flow and Logistics IML and for Factory Operation and Automation IFF in the Fraunhofer Group for Production are pooling their expertise on restructuring and designing transport infrastructures as well as delivery and production networks.

This involves using a variety of approaches so that resilience indicators are recorded not only for delivery and logistics networks, but also for infrastructures across the various modes of transport. These indicators are used to plan and monitor resilient and reliable delivery concepts and processes so that after disturbances occur, the effects on logistics can be identified and analyzed.

The digitalization of logistics processes is making comprehensive data for this analysis increasingly available, as technology is now used at object level with defined scan points in the long logistics chains, e.g. at goods receipt and dispatch, and using transport telematics. The near real-time availability of information about freight as a logistics object significantly increases

responsiveness to anomalies in logistics because it also measures the economic production capacity of the individual company – an important contribution to the “prevention” phase of the resilience process. Technical solutions for freight scanning that record a wide range of freight characteristics also have great potential for the “recovery” resilience phase – e.g. in the event of data loss in the IT system.

On a micro-, meso- and macro-logistics level, jointly discussing threat scenarios allows various stakeholders, such as companies, sectors, regions and legislators, to devise the appropriate measures. Once action areas for increasing resilience in the company have been assigned a location and prioritized, the next step is to develop possible courses of action and measures for dealing with the conflict between the goals of increasing resilience and reducing costs. An optimal balance of resilience and costs is crucial for acceptance.

Generally adaptable and highly flexible logistics networks support the development and implementation of new products, services and business models for resilient logistics services and infrastructures, which also safeguard the operational performance of complex production networks.

The operational safeguarding of economic processes is always based on the availability of reliable resilience indicators and real-time information at the physical goods transfer point – the transfer of risk between two stakeholders in a logistics network.

Outlook

As an independent, non-profit-oriented stakeholder, Fraunhofer can successfully support partners from government and industry in building up the core abilities that are key to increasing resilience. As the above-mentioned examples clearly show, the integrative approach by Fraunhofer can support the promotion of resilience on very different levels. These range from the overall political-economic system through value and supply chains, right down to individual companies.

Prof. Dr. Jakob Edler, Dr. Florian Roth
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Fraunhofer Institute for Material Flow and Logistics IML

Prof. Dr. Julia C. Arlinghaus
Fraunhofer Institute for Factory Operation and Automation IFF

New initiatives and infrastructures



Implementing the recommendations of the Fraunhofer Future Commission

The overall objective of the **Future Commission** established by the Executive Board was to develop and implement a future-proof structure for Fraunhofer. Impact Goals and Fraunhofer Strategic Research Fields were initially developed and launched in 2020. Structural elements such as the expertise-based **groups and lead-market-oriented alliances** were also launched. The Fraunhofer tool set has been further expanded to include partially virtual platforms such as **High-Performance Centers, Clusters of Excellence, Research Fabs** and **lighthouse projects**.

Impact Goals

The five Impact Goals set out social and cross-industry challenges to which Fraunhofer can contribute meaningful solutions. They offer a clear blueprint for government, industry and society – and they highlight our researchers' aspirations for themselves and their work.

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

Expertise-based groups

In 2020, the groups underwent a strategic process that resulted in the establishment of three new groups, from the breakup of the former **Life Sciences** Group in particular.

Expertise-based groups



Rotor blade bearings measuring up to 6 meters in diameter are tested for offshore wind farms on the BEAT6.1 large bearing test bench at Fraunhofer IWES.

Fraunhofer Group for Energy Technologies and Climate Protection

In line with the motto “There is no Planet B”, the Fraunhofer Group for Energy Technologies and Climate Protection intends to direct its activities to help accomplish the energy transition and reduce changes to climate conditions by avoiding emissions that are harmful to the environment. Achieving climate neutrality by means of technology is one of the most important goals of the Group. This is also being explored within the Fraunhofer-Gesellschaft itself. To ensure a responsible use of resources, the member institutes are developing biotechnological, process-engineering-based, circular and systemic solutions.

Political initiatives, such as the “New Green Deal” introduced by the European Union, the reform of the Emission Trading Scheme (ETS), the climate package introduced by the German federal government and amendments to the German Renewable Energy Sources Act (EEG), are generating increasing pressure for companies to innovate. Fraunhofer has already played a significant role in the previous successes of the campaign to eliminate fossil fuels from the energy system – for example, power generation costs have been reduced by 90 percent using photovoltaic systems. To achieve further cost reductions, greater reliability and a longer service life for all relevant technologies for generating, distributing and storing energy as well as its actual use, great efforts in research and development are still required. For the energy transition, this also involves implementing system integration in all consumer sectors, including buildings, industry and transport. Additionally, factors from the bioeconomy – production in closed loops – and the digitalization of the energy system must be considered in cooperation with other Fraunhofer Groups.

The Group for Energy Technologies and Climate Protection provides expertise for the “Energy Sector” lead market and the Fraunhofer Strategic Research Fields “Resource Efficiency and Climate Technologies” as well as “Hydrogen Technologies.” It includes the Fraunhofer Hydrogen Network, in which 28 institutes are helping to develop a hydrogen economy in Germany and Europe. The Fraunhofer hydrogen road map has already been incorporated into the national hydrogen strategy in Germany.

The group is directed toward manufacturers of energy systems and energy infrastructure, the energy sector, the mining and exploration industry, the production industry and other emission-intensive industry sectors with applied research. From 2021, the ENIQ showroom in Berlin-Schönefeld is providing an interaction platform for communicating the results of energy research, thus enabling energy transition and climate protection stakeholders to make informed decisions.

Its members include the Fraunhofer Institutes for Solar Energy Systems ISE, for Energy Economics and Energy System Technology IEE, for Wind Energy Systems IWES and the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG.

Fraunhofer Group for Resource Technologies and Bioeconomy

The UN Agenda 2030 with its 17 Sustainable Development Goals focuses on sustainable management of global resources while maintaining prosperity at the same time. To achieve this, economies must be supplied with sustainable resources and produce their products in an environmentally friendly way in the future. At the same time, social and environmental standards must be developed further and questions of justice must be addressed.

To achieve the social goals relating to raw materials and energy supplies, climate and environmental protection and safeguarding food and health, the Group is pooling biotechnological, process engineering and engineering expertise. As a systemic innovator, it is focusing on the research topics of

resource efficiency, circular economy, environmentally friendly raw materials and bioeconomy. Products, processes and services are being developed and used in accordance with the principles of bioeconomy in various sectors of the economy. This results in new chemicals, raw materials and building materials or medicines, for example, that have a positive effect on the environment and climate. The manufacturing of biopharmaceutical products represents an economically significant sector, for example.

The member institutes are addressing issues such as resource management in geological, biological and technological domains, as well as chemical and biotechnological processes for efficient conversions into product prototypes and products, including their assessment for environmental and consumer safety. This applies to the path from molecules through materials to products (product development) as well as the path from laboratories to production plants (scale-up process engineering methods).

The Group uses its know-how to address the Fraunhofer Strategic Research Fields "Resource Efficiency and Climate Technologies," "Hydrogen Technologies," "Bioeconomy" and "Artificial Intelligence". The developments are incorporated into the lead markets "Plant, mechanical and vehicle engineering," "Construction industry," "Energy sector," "Chemical industry," "Food industry," "Digital economy" and "Healthcare sector".

A landmark in the circular economy, the Fraunhofer Cluster of Excellence Circular Plastics Economy CCPE® has already been established. The Group is participating in the 2020 Fraunhofer innovation program with its collaborative projects "Sovereign Value Cycles – SVC" and "Evolutionary Bioeconomic Processes – EVO-BIO C," and with process development in automated pharmaceutical production.

The Group can build on Germany's leading international position in bioeconomy. Germany's cross-sector "National Research Strategy BioEconomy 2030" was published as early as in 2010, followed by the updated "National Bioeconomy Strategy" in January

2020. Dr. Markus Wolperdinger was appointed as a member of the Bioeconomy Council of the German federal government.

Members include the Fraunhofer Institutes for Environmental, Safety and Energy Technology UMSICHT, for Interfacial Engineering and Biotechnology IGB, for Process Engineering and Packaging IVV and for Molecular Biology and Applied Ecology IME.

Fraunhofer Group for Health

The fast growth of the world's population and the demographic change in the industrial countries are important determining factors for the healthcare sector. To counter the cost pressure that weighs on the community founded on the solidarity principle, cost-aware strategies and more efficient development of innovative treatments are required.

The Group focuses on the economically highly relevant medical fields of immunology and oncology as well as metabolic, neuro-degenerative and infectious diseases. Treating these immune-mediated diseases presents particular medical challenges. The automated manufacturing of cell and gene therapy products, genome editing and the development of novel classes of pharmaceuticals as well as biomarkers are the priority R&D trends. The member institutes can expand and build on joint research work: Examples include the Fraunhofer Cluster of Excellence for Immune-Mediated Diseases and the EU project "imSAVAR" with the aim of better assessing the efficacy and safety of immunomodulating treatments.

The Group also focuses on solutions for integrated precision medicine in digital medicine. In cooperation with the Fraunhofer ICT Group, data analysis and artificial intelligence are playing a particularly important role here. In the Fraunhofer lighthouse project MED²ICIN, for example, health and illness data is merged to ensure long-term cost-aware patient care. Other goals of the group include the design of development and manufacturing plants for cell therapy products or other innovative medications, further development of a shared Medical Data Space and intensification



Top:
Flexible, transparent organic solar modules can open up new fields of application.

Center:
The Altmarkt-Garten, a greenhouse on the roof of Jobcenter Oberhausen, serves as a research laboratory for inner-city food production for Fraunhofer UMSICHT.

Bottom:
Dr. Nadine Schneider (right) and her team at Fraunhofer ITMP working on an innovative vaccine for rheumatoid arthritis.

of the joint proof-of-concept initiatives with the Helmholtz Association and the German university hospitals (VDU).

As one of the largest and most important markets in any economy, the healthcare market is the focus of the Fraunhofer "Healthcare sector" lead market. R&D expenditure in the pharmaceutical industry, which has been increasing exponentially for years, is facing a stagnating number of new innovative drug approvals – and thus revenues. There is often a lack of predictive models for effectiveness and tolerance in relation to substances under development. Here, approaches to treating illnesses could benefit from a comprehensive understanding of the underlying complex clinical principles.

Germany plays a key role in health research worldwide. In 2018, the German federal government's research expenditure amounted to €2.5 billion – more than all other sectors. In terms of the number of industry-financed clinical studies, Germany ranks third worldwide, after the United Kingdom and the U.S. The importance of health research in Germany was also impressively demonstrated during the COVID-19 pandemic.

Members include the Fraunhofer Institutes for Biomedical Engineering IBMT, for Translational Medicine and Pharmacology ITMP, for Toxicology and Experimental Medicine ITEM, for Cell Therapy and Immunology IZI and its branch Bioanalytics and Bioprocesses (IZI-BB), for Digital Medicine MEVIS and the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE.

The Fraunhofer ICT Group, the Fraunhofer Group for Innovation Research, the Fraunhofer Group for Light & Surfaces, the Fraunhofer Group for Microelectronics, the Fraunhofer Group for Production and the Fraunhofer Group for Materials and Components continue to exist. The former Life Sciences Group has merged into the new groups.

New institutes and research institutions

Fraunhofer Institute for Translational Medicine and Pharmacology ITMP

The former institute branch Translational Medicine and Pharmacology in Frankfurt am Main and the Screening Port location in Hamburg, both of which were previously integrated into the Fraunhofer Institute for Molecular Biology and Applied Ecology IME, were merged in early 2021 to form the independent Fraunhofer Institute for Translational Medicine and Pharmacology ITMP. In addition, a collaboration in the area of "translational neuroinflammation" with the Göttingen University has resulted in the establishment of a new project group of the same name.

Research at the new Fraunhofer ITMP focuses mainly on the search for new active ingredients, highly specialized model developments in preclinical research and indications in clinical research. The institute will be able to use its expertise to ensure a better understanding of new approaches to treating and diagnosing major conditions that fall under the umbrella of immune disorders. It thus contributes significantly to the Fraunhofer Impact Goal of "Affordable healthcare" and to the "Digital Healthcare" Fraunhofer Strategic Research Field.

With its headquarters in Frankfurt, Fraunhofer ITMP is already anchored in the Frankfurt Rhine-Main pharmaceutical region. This institute branch is one of the founding members of "House of Pharma & Healthcare e.V." In close collaboration with the Frankfurt am Main university hospital, it is set to become an integrated care (university hospital) and

Automated production of vaccines and cell and gene therapy products will take place at the new Fraunhofer Institute for Translational Medicine and Pharmacology ITMP.



(Fraunhofer) research center for interdisciplinary medical studies on inflammation (4D Clinic). This is intended to accelerate the transfer of ideas and technologies, e.g. for new diagnosis and treatment options and for possible techniques for early detection and prevention of immune-mediated and neurodegenerative inflammatory diseases.

In 2012, the Frankfurt am Main location was established with funding from the LOEWE program (Hessian Initiative for the Development of Scientific-Economic Excellence). The Hamburg location was established following the integration of Screening Port GmbH into the Fraunhofer-Gesellschaft in 2014.

Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE

The former Fraunhofer Research Institution for Marine Biotechnology and Cell Technology EMB has been expanded to include the area of medical engineering. It can now tackle medical engineering issues ranging from basic research to equipment engineering and the translation of personalized instrumentation into clinics and industry. Individualized medical engineering is the answer to a growing demand for precise diagnostics that detect patient- and illness-specific influencing factors and use these to develop highly effective prevention, diagnosis and treatments measures with few side effects. The plan is to combine the new topics synergistically with the existing medical research topics. All other topics covered by the EMB in the areas of bioeconomy and biotechnology will be continued in an associated entity, the newly founded Development Center for Marine and Cellular Biotechnology EMB. The work done so far in this area can thus be expanded and the already established name EMB can be continued.

In close collaboration with institutes of the university of Lübeck, departments for individualized diagnostics and treatment will be established and existing cell technology will undergo further development. This will be complemented by cross-sectoral topics, such as individualized additive manufacturing, artificial intelligence, modeling and simulation, regulations and a unit for medical studies. With this expansion, the research institution is systematically aligning its services and developments in this business unit with the process of getting approval for medical products and bringing them to the market and in so doing, is actively contributing to translation into clinical trials and the commercialization of personalized medical engineering. In addition to keeping patients healthy, a healthy lifestyle as well as environmental and climate protection also continue to play an important role in the further development of Fraunhofer IMTE/EMB. The Fraunhofer research institution at Lübeck thus combines the two important factors for a healthy life under the one roof.

The Fraunhofer Research Institution at Lübeck is part of the Life Science Nord (LSN) cluster and has been collaborating with the EMB's "Cryo-Brehm" biobank to develop one of the largest archives worldwide for cell cultures from wild and farm animals. With its central focus on marine biotechnology, it is an important partner in the food industry as well as in the foodRegio industry network.

Lead-market-oriented alliances

Fraunhofer established an important new transfer structure in 2020 with the **lead-market-oriented alliances**. They are defined as cooperative technology transfer platforms for so-called lead markets, i.e. sectors that are of particular relevance for the innovative drive in Germany and Europe. The objective is to use innovations to achieve a global competitive advantage for Germany, safeguard the technological sovereignty of Germany and Europe and generate sustainable value creation for society.

In 2020, lead-market-oriented alliances were launched to address the following lead markets:

- Plant, mechanical and vehicle engineering
- Construction industry
- Energy sector
- Healthcare sector
- Mobility sector
- Digital economy
- Chemical industry

The alliance for addressing the "Agriculture and food industry" lead market is kicking off in 2021.

The lead-market-oriented alliances will serve as "one-stop shops" for the entire value creation process in their sectors: Through pooled expertise, comprehensive research products and services, and adaptable, agile project consortia, they are intended to unlock new potential and leverage synergy effects. As platforms for working collaboratively in associations and committees, they also help to make an impact at economic and social levels.

New research institutions planned from 2022



Presenting plans for a new research institution for immunology, infection and pandemic research in Penzberg, Hamburg, Potsdam and Berlin: (from left) Prof. Dr. Thomas Gudermann, LMU Munich; Fraunhofer President Prof. Dr. Reimund Neugebauer; Alexander Dobrindt, CSU; Penzberg's First Mayor Stefan Korpan. Virtually connected: Claus Haberda, Roche Diagnostics.

To combat the coronavirus pandemic, the German federal government launched a bold emergency stimulus package aimed at overcoming the medical challenges as well as the social and economic crisis. In November 2020, the budget committee approved a budget of €1.2 billion for education and research. The set of measures from Fraunhofer was considered for three initiatives. As a result, plans are in place to establish three new research institutions in the coming years:

- **Immunology, infection and pandemic research**
in Penzberg, Hamburg, Potsdam and Berlin

The high rate of innovation in the medical field was also reflected during the crisis brought about by the pandemic, with examples including the development of apps, active ingredients and vaccines. Technology-driven innovations offer great opportunities for efficient healthcare in Germany and Europe. For immune-mediated diseases, all the relevant partners in the German research landscape will pool their expertise in one national cluster in future. The existing areas of expertise will be expanded to include four complementary focal points:

- Immunological infection and pandemic research: At Penzberg, the aim is to work together with Roche Diagnostics GmbH in a strategic partnership to characterize the role of the immune system in infectious diseases and immune reactions.
- Immunological biomarker research: At Hamburg, researchers intend to identify biomarkers that can easily be measured, so that conclusions can be formed regarding the efficacy of treatment approaches for immunological diseases.
- Digital diagnostics: At Potsdam, research will be carried out on the practical applications of digital diagnostics, with the aim of enabling wide-scale telemedical care for the general population.
- Allergology: At Berlin, studies will be conducted to decipher the mechanisms of allergic diseases and develop new diagnostic and therapeutic approaches for allergic inflammatory diseases.

■ **Public safety and security** in Berlin

This Germany-wide network aims to pool research, development, and testing for security-related technologies, innovations and systems, with a focus on human and data intelligence. Federal structures will be incorporated into it and will be served efficiently. For the network's target groups, especially state and federal authorities and related security organizations, the advantages do not just lie in having easy access to technological advice and expertise, but also in the fact that technological prototypes can be developed, built and tested through cooperative research and development.

■ **Biogenic value creation and smart farming** in Bavaria and Mecklenburg-Vorpommern

From seed to enriched product, grown both on land and in water – the planned shared center will focus on innovative technologies for sustainable agriculture along the whole value chain. Each location is intended to act as a nucleus for regional innovation ecosystems consisting of established businesses, innovative start-ups and specialized research institutions, and create highly qualified jobs and training positions. In addition to developing advanced, sustainable, resource-efficient technologies, the center will assist farmers in the transformation processes that they must implement due to climate change and in issues relating to sustainability; it will also establish regional value creation networks. The main focus will be on sustainability in cultivation, taking into account the environment, consumer health, social stands and animal welfare.

New ways of processing products support transformation in the agricultural sector.



- The locations in Bavaria will direct their efforts toward providing technological assistance in producing certain plants that have been chosen as examples of species with major relevance for regional agriculture and food supply – from cultivation through harvesting and up to application. The goal is to find innovative ways of processing agricultural products with a view to maximizing food safety and product quality along the value chain.
- In Mecklenburg-Vorpommern, research and development work will focus on technologies for sustainable agriculture that are designed to unlock potential in water and on land. Staff at the Rostock location will primarily conduct research on digital and robotic solutions for efficient, sustainable, and individualized plant and animal production. The agricultural sector includes not only traditional farming, but also the use of the sea and other bodies of water for the production of food and other usable materials.

Initiatives for reducing CO₂ using hydrogen and electrification

Research Fab Battery Cells FFB

The construction of the Research Fab Battery Cells FFB in Münster, which began in October 2019, is progressing faster than planned. In addition to nine Fraunhofer Institutes, research partners at the University of Münster and RWTH Aachen are collaborating as research partners on the funding project by the federal government (German Federal Ministry of Education and Research) and the State of North Rhine-Westphalia. In 2020, initial milestones such as defining the plant design for the first production line for round cells were already achieved.

In fall 2020, the German federal government and the State of North Rhine-Westphalia decided to bring forward the final expansion in response to FFB user requirements. This step involved constructing another production line and a prototype and sample line completely from scratch, with the result that all three standard lithium-ion battery cell formats – round cells, pouch cells and prismatic hard-case cells – can be manufactured immediately in the FFB. This guarantees a flexibility that

is geared to the needs of the industry, while simultaneously providing optimal scientific utility.

The FFB focuses on the production of modern, high-performance energy storage systems – not just for e-mobility, but also for applications in domestic settings, industry, logistics, the energy sector, chemistry, mechanical and plant engineering and robotics. The FFB will develop the framework conditions for developing battery cell production in Germany, in order to eliminate dependency on East Asian markets in the medium term. A consortium led by the Münster-based battery researcher Prof. Dr. Martin Winter is collaborating with Fraunhofer experts to make the FFB a reality and run its operations; other universities and scientific institutions in Duisburg-Essen and Bochum, for example, are also involved.

In December 2020, an initial virtual interim solution developed by the FFB using early work on digital twins went into operation. The plan is for the FFB to begin its work in the Hansa Business Park in Münster in early 2022. In the coming years, the state will invest

The Research Fab Battery Cells FFB, a new branch of the Fraunhofer Institute for Production Technology IPT located in Münster, is to become the center of development for modern battery cell production.



a total of around €200 million in constructing the FFB and in the targeted promotion of young talent on site.

National action plan for fuel cell production

If we succeed in manufacturing and using hydrogen efficiently in all energy consumption sectors, this could play a central role in the transformation of our energy systems. The fuel cell is a key factor in CO₂ reduction, especially in the transport sector. The goal of the “National action plan for fuel cell production” is to develop and advance the technologies required for industrial mass production. To achieve this, 20 Fraunhofer Institutes are pooling their existing research expertise and initiatives at locations in Baden-Württemberg, Bavaria, Lower Saxony, North Rhine-Westphalia and Saxony.

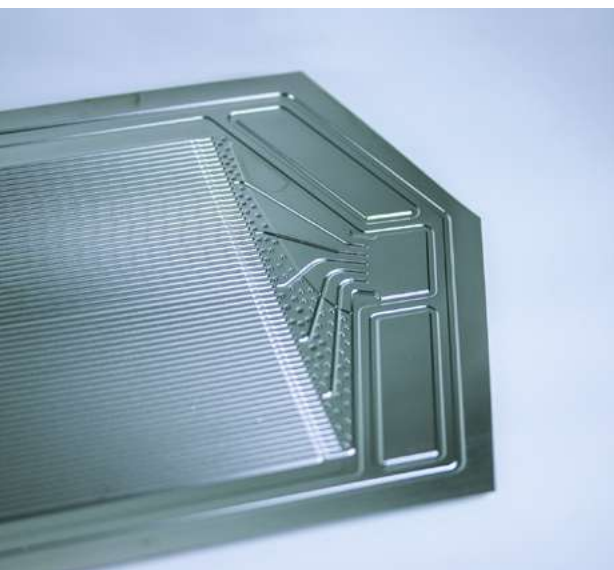
This decentralized model will be supplemented by a central nexus in the form of a virtual reference architecture. This facilitates the rapid transfer of technology into wide-scale use and visible participation of the industry throughout Germany and internationally. The action platform has three main objectives: cost-optimized, needs-oriented, scalable mass production, comprehensive technological and industrial development of the potential of fuel cells and considerable acceleration and expansion of the structured rollout in industry and society.

A swift rollout of mass-produced, cost-efficient fuel cells will create opportunities for hydrogen, not only in terms of climate policy, but also for sustainable value creation. It is precisely the critical components of hydrogen system technology – the use of fuel cells in transport solutions of varying performance categories – that present enormous potential for value and job creation. This means that fuel cell production can be developed into a key area of expertise for German companies, thereby ensuring the long-term suitability of German mechanical and plant engineering for exports. The Fraunhofer Institute for Machine Tools and Forming Technology IWU is responsible for the overall coordination of the national action plan.

Battery Innovation and Technology Center (BITC)

Linked to the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, the Battery Innovation and Technology Center (BITC) was opened in Arnstadt, Thuringia. Its goal is to ensure the highest possible quality in battery production with minimum waste. Defects are identified early on in the production process using innovative non-destructive testing technology. In the 5000-square-meter facility, researchers are working on solutions for networked production of energy storage devices. Researchers test innovative data-driven approaches for process monitoring, control and quality assurance in industry-scale pilot lines. In addition to battery development issues, Fraunhofer IKTS is developing basic routines for scalable production of complex energy storage devices and converters. The experience gained from battery research will also be applied to digitally supported production technologies for electrolyzers in the hydrogen economy in the future. Application-oriented training and further education programs are also being employed to ensure companies along the entire value chain are involved and have the necessary qualifications.

Its goal is to ensure the highest possible quality in battery production with minimum waste.



Technology-optimized stainless steel bipolar plates for PEM fuel cells, manufactured at the Fraunhofer Institute for Machine Tools and Forming Technology IWU.

Model project “Green Hydrogen for Bremerhaven”

The Fraunhofer Institute for Wind Energy Systems IWES launched the model project “Green Hydrogen for Bremerhaven” in the Lune Delta business park in Bremerhaven in 2020. Using hydrogen for molecular energy storage is a central component of the energy transition. The project is laying the foundations for a hydrogen center of excellence comprising the entire value chain – from production and storage to practical testing.

Among others, the AD8 wind turbine in the southern fishing port, is to provide the renewable power for splitting water into hydrogen and oxygen via electrolysis, and thus for producing hydrogen in a CO₂-neutral manner. The construction of an electrolyzer test field on the site of the former Luneort airfield is also commencing. Fraunhofer IWES plans to achieve an electrolysis output of 2 megawatts (MW) initially, and is preparing a further eight test pads for a total of up to 10 MW in electrolysis output. They will be connected to the institute’s nearby Dynamic Nacelle Testing Laboratory (DyNaLab). A connection to one of the world’s most powerful dynamic power grid emulators makes it possible to examine

the impact of power supply fluctuations on the electrolyzers, among other factors.

Together with its project partners, the Bremerhaven University of Applied Sciences and the Bremerhaven Technology Transfer Center (ttz), Fraunhofer IWES is investigating applications in the fields of logistics and transport as well as the food industry, in order to replace fossil fuels with hydrogen at least to some extent. Fraunhofer IWES will test the operation of an offshore measuring buoy. In the process, the energy required for continuous data recording out at sea will be provided by a fuel cell. These new activities draw on local scientific expertise and existing research infrastructure for wind energy and process engineering. In the model project, the project partners Fraunhofer IWES, Bremerhaven university and ttz Bremerhaven investigate the potential of green hydrogen, thereby paving the way for economic CO₂-reduced industrial processes as well as flexible and resilient power and energy systems. The model project is funded by the State of Bremen and the European Union (ERDF).

Electrical energy can be stored in the form of hydrogen using electrolysis.

Competence center for electric flight in Kamenz

The Fraunhofer Institute for Material and Beam Technology IWS is a founding member of the new competence center for autonomous and electric flight at the airfield in Kamenz, Saxony. The focal topics are battery and hydrogen technology, swarm applications, data transmission and security as well as autonomous navigation using artificial intelligence. Fraunhofer IWS is participating in the initiative with next-generation batteries and providing a link to the Battery Center in Dresden. In addition to the city of Kamenz, the network includes universities, more than 20 companies as well as partners in Thuringia, Brandenburg, France, Poland and the Czech Republic.



Quantum technology initiatives

To drive applied research in the area of quantum computing, the Fraunhofer-Gesellschaft established the centrally coordinated “Fraunhofer Competence Network Quantum Computing.” At the heart of the network is the IBM Q System One quantum computer, which is situated in Ehningen in Baden-Württemberg and is for the exclusive use of the Fraunhofer-Gesellschaft and its partners. The quantum computer has been ready for use since early 2021 and is operated under German legislation, which is an important advantage for users in terms of data protection and IP security. Cloud access to IBM quantum computers in the U.S. has been available since April 2020.

The network is divided into seven regional competence centers, each with its own research focus. These regional competence centers work closely with partners and customers from research and industry. They also offer a collective, multi-level training and further education program, which includes various courses as well as expert advice on questions concerning the use of quantum computers. The network is managed by a board of directors consisting of institute directors from the participating competence centers. An advisory board also provides expert advice on strategic issues. The network’s branch office at the Fraunhofer headquarters in Munich forms an overarching link between the various regional activities. In terms of research topics, starting points for collaboration include the Fraunhofer Strategic Research Fields “Quantum Technologies” and “Next Generation Computing” in particular.

The network is the first contact point in Germany for companies and research organizations that want to carry out research on and with the quantum computer. It not only supports experts who want to develop and

test their own algorithms on the quantum computer, but also first-time users who would like to find out more about quantum computing in general and to make initial contacts in this field. The performance parameters of the quantum computer are aligned to the high demands of a research infrastructure with a focus on economically relevant applications. There is a broad range of potential areas of application, with high relevance for a wide variety of sectors, such as logistics, the chemistry and pharmaceutical industry, the finance and energy sector, engineering and materials science, communication technology and IT security technology. The infrastructure gives the local economic and innovation landscape a clear competitive advantage, huge potential for developing expertise and safeguarding intellectual property as well as the possibility of making informed decisions about future investments.

The heart of the “Fraunhofer Competence Network Quantum Computing” is the IBM Q System One quantum computer.

Setting up the IBM Q System One quantum computer.



Initiatives for data sovereignty and digitalization

National
GAIA-X hubs
have already
been estab-
lished in
Germany,
France and
Belgium.

GAIA-X

Fraunhofer is a material influence on the architecture of the pan-European GAIA-X project co-initiated by the German Federal Ministry for Economic Affairs and Energy. Currently in the founding process, GAIA-X AISBL (the legal form for non-profit associations under Belgian law) is the organization that will set the European standard for cloud computing. To assist in this purpose, 11 German organizations (including BOSCH, Deutsche Telekom, eco-Verband, Fraunhofer, German Edge Cloud, IDS Association, SAP and Siemens) and 11 French organizations (including ATOS, Dassault and Orange) have joined GAIA-X AISBL. Over 200 other organizations from 15 nations have already expressed a definite interest in joining.

GAIA-X allows the creation of data ecosystems that fulfill the European standards of openness, transparency, interoperability and trust, and strengthens data sovereignty on the basis of an open standard for data infrastructures. Technologically, GAIA-X builds on the work of the "International Data Spaces Association" (IDSA), which was co-founded by Fraunhofer in 2015. The IDS reference architecture developed there is used to ensure that during data exchanges between companies, terms of use for the data are also exchanged.

The first certified GAIA-X applications, e.g. transport, Industrie 4.0, healthcare, energy, finance and aerospace, are expected in mid-2021. National GAIA-X hubs have already been established in Germany, France and Belgium and there another ten hubs at the discussion stage in EU countries.

Silicon Economy

The "Silicon Economy" project in the Ruhr area of Germany is creating a digital platform

for the B2B sector – an ecosystem similar to that created by Amazon, Uber, Airbnb and others in the private customer sector. The goal of the consortium partners is the end-to-end digitalization of complete process and supply chains using artificial intelligence.

Individual hardware and software components for automation and new business models involving blockchains are developed for and with logistics companies and made available free of charge in an open source library. The objective is to support the logistics industry and enable it to develop its position on the world market. As its data space, the Silicon Economy project uses the architecture of the International Data Spaces Association, of which Fraunhofer is a founding member.

The consortium partners are already working on the first concrete logistics use cases. In a project on digital load carrier exchange processes, a standardized, cross-sector digital exchange slip for EUR-pallets, small load carriers and crates is being developed. Research is also being conducted on an AI-based service that enables logistics companies to keep their customers reliably informed about when their goods will arrive. Prof. Dr. Michael ten Hompel, director of the Fraunhofer Institute for Material Flow and Logistics IML, believes that "whoever controls the world's logistics chains controls the world's economy." The German Federal Ministry of Transport is providing a total of over €25 million in funding for the project over a period of three years.

5G Bavaria test center

The "5G Bavaria" initiative funded by the State of Bavaria combines a 5G test center and two test beds for Industrie 4.0 and automotive applications at the Fraunhofer Institute for Integrated Circuits IIS in Erlangen and Nuremberg. The initiative supports the transition from

research and standardization to application. Companies are given the opportunity to test out laboratory-based simulation and emulation processes as well as a real 5G mobile communication environment. In the Industrie 4.0 5G test bed at Fraunhofer IIS in Nuremberg, customer-specific applications for industry and logistics can be tested under real-life conditions in a stand-alone 5G campus network. For example, complex, safety-critical applications such as in human-machine interactions can be conducted wirelessly. A test infrastructure for 5G functionalities is being developed in a real mobile communications environment in the automotive 5G Bavaria test bed. Both test beds are being developed and operated in cooperation with the Fraunhofer High-Performance Center Electronic Systems LZE e. V.

European Blockchain Institute at Fraunhofer IML

The North-Rhine Westphalia European Blockchain Institute in Dortmund is closely inter-linked with the "Silicon Economy" project, and came about within the framework of the project. At this institute, the Fraunhofer Institutes for Material Flow and Logistics IML and for Software and Systems Engineering ISST are working together with companies and other research institutions to advance blockchain technology in a decisive way. As a key technology with transparent and decentralized registers, blockchain technology has the potential to make data exchange tamper-proof and to automate and autonomize a multitude of processes in the value chain.

With their blockchain device for monitoring temperature-sensitive goods such as food products, medicines or vaccines along global supply chains, the scientists have already presented a pioneering prototype. Scientists expect that the impact of blockchain technology will be fully felt for the first time in coming years – particularly in the logistics industry. In interaction with digital platforms, artificial intelligence and the Internet of Things, a new, self-organizing "Silicon Economy" is emerging.

The project consortium of the European Blockchain Institute consists of the Fraunhofer

Institutes for Material Flow and Logistics IML and for Software and Systems Engineering ISST as well as the chair of Corporate Logistics and the chair of Materials Handling and Warehousing at the TU Dortmund University. The NRW Ministry for Economics and Digitalization is providing funding amounting to approximately €7.7 million.

5G4KMU transfer center in Baden-Württemberg

5G enables demand-driven connectivity with high bandwidth, low latency and a high number of connections. In this way, 5G represents an important foundational element for applications in Industrie 4.0, intelligent transport and logistics as well as for the Internet of Things.

Coordinated by the Fraunhofer Institute for Manufacturing Engineering and Automation IPA, test environments are being set up at five locations in Baden-Württemberg as part of "5G4KMU," a 5G transfer center for small and medium-sized enterprises. The purpose of the center is to develop applications in Industrie 4.0, intelligent transport, logistics and the Internet of Things for SMEs. Companies can collaborate with the research institutions to test and advance their project ideas through feasibility studies or needs analyses, for example.

The blockchain device allows monitoring of temperature-sensitive goods along global supply chains.



This collaboration can be continued in the form of “exploring projects.” In this format, implementation plans are developed, converted into prototypes and tested in a 5G network consisting of five test environments.

- **Stuttgart**, Fraunhofer IPA: 5G in factories and production systems; Fraunhofer IAO: Smart services and smart products based on 5G
- **Mannheim**, Fraunhofer IPA project group for automation in medicine and biotechnology: 5G in clinics and laboratories
- **Freudenstadt**, Centrum für Digitalisierung, Führung und Nachhaltigkeit Schwarzwald (Campus Schwarzwald): 5G in production with focus on mechanical engineering
- **Reutlingen**, Reutlinger Zentrum Industrie 4.0: Logistics applications and identification and development of new fields of business for medium-sized companies
- **Karlsruhe**, wbk Institute of Production Science at the Karlsruhe Institute of Technology (KIT): Forward-looking maintenance of machines and intelligent data evaluation

Discussion paper by the advisory council for cybersecurity

In 2019, Cyber Security Cluster Bonn e.V. established the independent advisory council for cybersecurity (Weisenrat für Cyber-Sicherheit). In 2020, the six renowned professors from the most important clusters of excellence in Germany published their first report on pressing digital security issues and submitted them to the German federal government. In this report, they proposed eight recommendations for action with the aim of helping to render society immune to cyber-attacks.

- Technology must adapt to people in order to relieve pressure from them and protect them.

- Manufacturers must commit to perform regular vulnerability tests and security updates.
- Digital processes and infrastructures must be made more resilient against attacks.
- Technological sovereignty must be increased and preserved.
- Digital infrastructures in smart cities must remain available, comprehensible and manageable.
- AI systems must be transparent and subject to certification.
- Long-life products must be designed to be cryptographically agile.
- Online protection of democracy must be strengthened.

Members of the advisory council for cyber-security include Prof. Dr. Claudia Eckert, director of the Fraunhofer Institute for Applied and Integrated Security AISEC, and Prof. Dr. Matthew Smith from the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE.

German National Research Data Infrastructure

A significant amount of data from research projects or studies is still stored at universities or research institutions on a decentralized basis. The German National Research Data Infrastructure e.V. (Nationale Forschungsdateninfrastruktur e.V. – NFDI) intends to change this. Established in October 2020, its goal is to systematically make this information available to the scientific community and make it more easily accessible and usable within the framework of a comprehensive research data management system. In choosing Prof. Dr. Claudia Eckert (Fraunhofer Institute for Applied and Integrated Security AISEC) and Prof. Dr. Anita Schöbel (Fraunhofer Institute for Industrial Mathematics ITWM), the Joint Science Conference (Gemeinsame Wissenschaftskonferenz – GWK) run by the German federal government and the federal states appointed two Fraunhofer Institute directors to the senate of the NFDI.



Initiatives for artificial intelligence

Competence center for cognitive energy systems

Development of a competence center for cognitive energy systems at the Fraunhofer Institute for Energy Economics and Energy System Technology IEE is now underway with funding from the state of Hessen.

Until now, artificial intelligence (AI) has mostly been used for monitoring or forecasting purposes in the energy sector. As the share of power from renewable energy increases, it has become clear that AI will also play a key role in complex coordination and decision-making processes for managing energy systems in the future. This is because in a decentralized renewable energy supply system, different energy systems, such as power and heat supply as well as transport, must be combined on a large scale via automated decisions.

A concrete example of the need for AI in the energy sector is automated energy trading. Photovoltaic systems, wind farms, charging stations and even electrolyzers can use AI to optimize their operation, perform maintenance proactively and increase their service life. For power grids, the technology is used to evaluate data, in order to identify critical situations and help to resolve them. The development of an automated trading system for the EPEX Spot power exchange has already begun at Fraunhofer IEE in Kassel.

Cognitive security in Bavaria's High-Tech Agenda

At the Fraunhofer Institute for Applied and Integrated Security AISEC, applied research at the interface between IT security and artificial intelligence (AI) is being developed with a funding project on cognitive security. This will make it possible to conduct fundamental research work at the intersection between IT security and artificial intelligence. The researchers are developing not only secure AI-based solutions but also test and certification methods and concrete tools to assist companies in assessing the vulnerability of AI processes and implementing specific measures aimed at making them more "tougher." The cognitive security research project falls under the Artificial/Machine Intelligence competence network established as part of the Bavarian state government's High-tech Agenda.

Competence Center Karlsruhe for AI Systems Engineering CC-KING

The Competence Center Karlsruhe for AI Systems Engineering CC-KING offers companies concrete support in deploying artificial intelligence (AI) and machine learning (ML) techniques. With initial funding from the Ministry of Economic Affairs in Baden-Württemberg until 2021, the Karlsruhe center is conducting basic research in the area and developing tools for low-threshold systemic implementation of AI and ML in accordance with the technical and economic requirements of business practice. The aim is to take AI and ML algorithms from data scientists' toolboxes, harness them using the proven engineering procedures and simulate them at the systems engineering level used by computer scientists – even in safety-critical applications. To achieve this, it must be possible to make predictions and provide guarantees about intelligent systems that only reach their full functionality by collecting and analyzing data during actual operation. The initial focus is on the contexts of industrial production and transport. Existing research initiatives such as the Karlsruhe Research Fab and the Baden-Württemberg Test Area Autonomous Driving serve as living laboratories for the focal points.



Left:

The requirements for and potential of 5G in the manufacturing context are examined at Fraunhofer IPA.

Right:

Artificial intelligence algorithms create new conditions for highly efficient and secure systems.

AI certification “Made in Germany”

The lighthouse project “Certified AI” is kicking off in 2021 as part of the AI.NRW competence platform led by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS. Its aim is to establish verifiable technical standards and norms that enable a neutral evaluation of artificial intelligence (AI) systems and provide information about the promised properties of AI technologies. The German Federal Office for Information Security (BSI), the University of Bonn, the University of Cologne, the RWTH Aachen, the German Institute for Standardization (DIN), as well as numerous DAX-30 and other companies from various sectors such as telecommunications, banking, insurance, chemistry, and retail, are participating in the project. In industry- and technology-related user groups, the participants define concrete needs, establish criteria and benchmarks for testing in practice and conduct pilot tests. This broad participation process ensures that the processes develop into generally accepted standards for AI systems and testing, while simultaneously being supported by legal and ethical considerations.

AI study – Expertise and innovation potential in Saxony

The study “Artificial intelligence – Expertise and innovation potential in Saxony” was published at the beginning of 2020 by the Engineering of Adaptive Systems EAS branch of the Fraunhofer Institute for Integrated Circuits IIS. It describes how companies and research are positioned as regards AI and the obstacles they face. It also highlights possible courses of action to help realize the state of Saxony’s goal of becoming a leading AI region in Germany.

Representatives from both industry and science view the shortage of skilled workers as the greatest challenge to overcome in the development and deployment of AI. The reliability of AI decisions, employee qualification and possible ways of accessing large volumes of data also play a key role. The comparatively small-scale structure of the economy in Saxony and its start-up culture also influence the speed of AI developments in the state.



Initiative for next-generation computing

A new location for the Center Nanoelectronic Technologies CNT

At the Center Nanoelectronic Technologies CNT, the Fraunhofer Institute for Photonic Microsystems IPMS is conducting applied microelectronics research on 300 mm wafers. In 2020, the CNT moved to a new independent location in Dresden. The state of Saxony acquired an empty cleanroom as well as offices and made them available for Fraunhofer IPMS for this purpose. A second construction phase includes plans to erect a new office and laboratory building by 2024. In the future, the new location will be used specifically for work on developing neuromorphic chip design with implemented AI, and processes, modules and structural elements will be developed right through to pilot production. The medium-term goal is to develop the new location in cooperation with other Fraunhofer Institutes into a globally recognized competence center for microelectronic technology research.



Initiative for security

GESTRA

Many of our critical infrastructures, such as navigation systems, now depend on satellites. These in turn are increasingly being endangered by space debris. NASA has created a global catalog to be able to warn satellite operators in time when a piece of debris is getting dangerously close to a satellite. However, this master catalog does not contain many of the American flying objects due to tactical reasons. Germany is hoping to free itself from this dependency using two radar systems. Since 1970, the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR has operated the space observation system TIRA, which tracks and images space objects. Since October 2020, a phased array radar with a high range and beam agility has been added to take over surveillance in a large section of space.

The partially mobile space surveillance radar GESTRA commissioned by the German Federal Ministry for Economic Affairs and Energy was designed and developed as an operational system at Fraunhofer FHR. The design

Left:

At the Center Nanoelectronic Technologies CNT, Fraunhofer IPMS is conducting research on 300 mm wafers for IC manufacturers, suppliers and equipment manufacturers.

Top:

The phased array radar with high beam agility allows better surveillance of the low earth orbit.

involves a quasi-monostatic system consisting of separate transmitting and receiving subsystems. The phased array antennas are each mounted on a three-axis positioner, enabling the user to first set the surveillance area mechanically and then scan this area electronically within milliseconds. In the process, the radar beams form a type of fence that can be likened to windshield wipers. Every object that is large enough and passes through the fence will be detected.

In September 2020, the new space surveillance radar was handed over to the German Aerospace Center e. V. (DLR) in Koblenz as well as the Space Situational Awareness Center. In order to create a German master catalog, the Space Situational Awareness Center controls GESTRA via remote control using 2000 built-in sensors. If there is more interest in a specific object, the center will in turn task Fraunhofer FHR with tracking and imaging this object using TIRA. In the long run, interconnecting multiple GESTRA systems would help to determine positioning with significantly greater accuracy. This is why GESTRA was designed as a partially mobile system.

Initiatives for bioeconomy, resource efficiency and climate technologies



Left:

In the future, sustainable carbon fibers will be manufactured at the current location of the lignite-fired power plant in Boxberg.

Right:

The Plastics Technology Center Oberlausitz, which was recently expanded, is opening up new possibilities for the future.



Green carbon fibers from a coal-fired power plant

A power plant in Boxberg in the Lausitz lignite mining region is to be given a new prospect for the future. The aim of the InnoCarbEnergy project is to design and develop a research pilot line for the manufacture of sustainable carbon fibers, so that new manufacturing processes and associated methods of energy management can be developed in parallel. There are also plans to expand the pilot line to include production modules for textile and plastics technology as well as automated interfaces for energy-efficient component production. The objective is to work together with local companies to develop carbon fiber-reinforced lightweight structures and systems that have enormous weight advantages and can be used in transport applications (such as in automotive, ship, rail vehicle or plant engineering construction or in the aerospace industry).

The planned activities are based on the German Federal Cluster of Excellence MERGE "Technology Fusion for Multifunctional Lightweight Structures" at Chemnitz University of Technology and the Fraunhofer Institutes for Machine Tools and Forming Technology IWU and for Applied Polymer Research IAP. Lausitz Energie Kraftwerke AG and Lausitz Energie Bergbau AG (LEAG) are also participating in the InnoCarbEnergy project, which is funded by the state ministry for regional development in Saxony.

Expanding the Plastics Technology Center in Zittau

The Fraunhofer Institute for Machine Tools and Forming Technology IWU will continue to develop its Plastics Technology Center in Zittau until 2022. This will significantly expand the research areas of lightweight engineering, industrial 3D printing and automation. The technology center will be developed into a large research hall with ultra-modern processing machines and analysis equipment. Collaborative projects with regional companies and SMEs are underway, for example, for manufacturing processes for wind turbines with natural fiber-reinforced plastics, integration of natural fibers for the plastics and lightweight engineering sector and efficient manufacture of complex plastic components in large-scale industrial 3D printing. A hydrogen scooter was developed in the hydrogen technologies research area. In the group project "WALEMO," plans are in place to develop self-driving, hydrogen-powered shuttles for a demand-driven short-range public transport system in rural areas. The Fraunhofer Plastics Technology Center Oberlausitz was established in 2011 as a project group on the campus of the Zittau/Görlitz University of Applied Sciences.

Lighthouse projects

futureAM – Next-generation additive manufacturing

A Fraunhofer consortium started the futureAM lighthouse project in 2017 with the goal of accelerating additive manufacturing of metal components by at least a factor of 10. By the end of the project in 2020, the six participating institutes had achieved technological advances in systems engineering, materials processing, process control, and end-to-end digitalization. This has made additive manufacturing more efficient and economical.

An XXL-scale (100 x 80 x 40 cm) demonstrator component was manufactured using laser powder bed fusion for the first time. The part in question was a component for future generations of Rolls-Royce engines and was manufactured using a new machine system that was equipped with a mobile optical system. The extreme high speed laser material deposition method was further developed for 3D printing. The newly developed process now allows extremely quick deposition speeds with high detail resolution.

Additive manufacturing of combined materials was improved by using artificial intelligence to record process analyses, which has resulted in an optimized manufacturing process for laser material deposition. At the same time, high-temperature materials can now also be combined in multi-material construction. The research team developed multi-material components made of nickel and aluminum, for example, with the possibility of adding other elements. The consortium also made significant advances in post-processing. A code for identifying the component is added during manufacturing, which means that at a later stage, it is possible to compare the target and actual geometry precisely during read-out and correct them automatically using a robot. This also ensures copy protection.

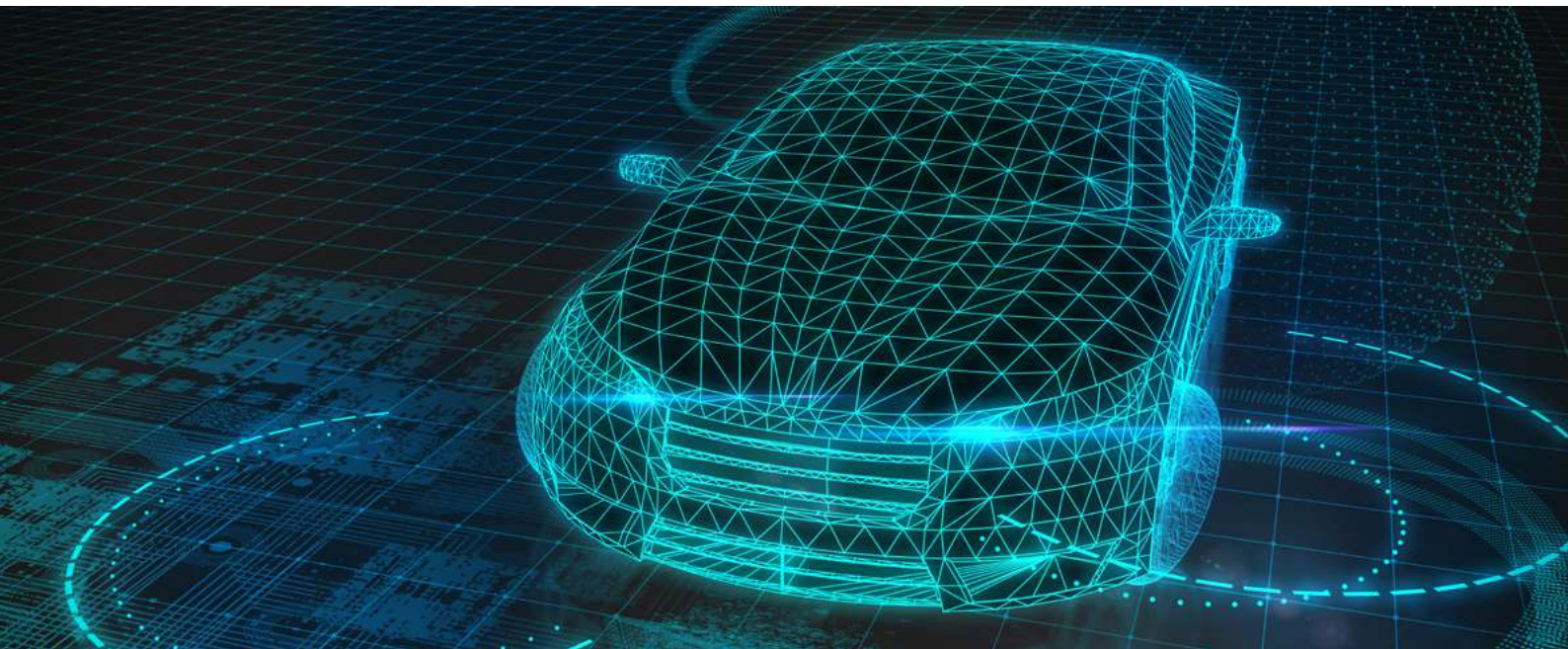
The partners focused on a holistic approach to digital and physical value creation, from receipt of the order to the finished 3D-printed metal component. As a result, the central point of the project was a virtual lab that pooled the different forms of expertise digitally and ensured the exchange of information across all task areas and stakeholders. Web-based simulation tools for designing additively manufactured metal components – tools that can also be used by beginners – were created in the virtual lab.

The Fraunhofer Institute for Laser Technology ILT (consortium leader), the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT, the Fraunhofer Institutes for Manufacturing Technology and Advanced Materials IFAM, for Computer Graphics Research IGD, for Material and Beam Technology IWS and for Machine Tools and Forming Technology IWU participated in the futureAM lighthouse project.

Additive manufacturing processes open up new possibilities. The further developed process now allows extremely quick deposition speeds with high detail resolution.



New lighthouse projects starting in 2021



6G, the next generation of mobile communications, is a prerequisite for self-driving vehicles.

After a moratorium due to the serious coronavirus situation in early 2020, lighthouse projects that are to start in 2021 were selected through an expedited fast-track process in the latter half of 2020. Five new lighthouse projects started on January 1, 2021.

6G SENTINEL – The next generation of mobile communications

In the 6G SENTINEL lighthouse project, development of basic technologies is underway for the next generation of mobile communications, 6G. It is intended that this will enable widespread use of applications such as virtual/augmented reality (XR), digital twinning, Industrie 4.0, self-driving vehicles, telepresence, and teleoperation.

According to forecasts, the data rate and reliability following the change from 5G to

6G will improve by a factor of 100, while latency and connection density will improve by a factor of 10. In addition to systematically continuing the development of 5G technologies, this requires innovative, disruptive approaches. The project partners are addressing these challenges through key technologies for 6G: terahertz technologies for mobile end devices, flexible networks with changeable infrastructure – particularly flying platforms and satellites – localization in 6G networks, and a complete understanding of 6G network architecture.

An overarching objective of the project is the development of a Fraunhofer vision for 6G system architecture to serve as the basis for the technology elements to be developed. Increasing the spectral efficiency and transfer rate through reusable frequency resources is crucial for 6G architecture, and will be achieved through minuscule cells

and antennae with integrated beamforming systems (massive MIMO), and by transitioning to higher frequencies (millimeter waves and THz). There is also a need to integrate small-cell and infrastructureless communication into the 6G network architecture for mobile Internet. As non-terrestrial base stations, satellites and flying platforms are intended to help bridge short distances and ensure widespread coverage outside of urban areas. Here, the core network must allow the integration of heterogeneous radio access networks with different ranges, frequencies, data rates and latencies.

For terahertz technology, the Fraunhofer consortium is developing radio channel models and link-level simulators for the frequency range between 100 and 300 GHz, a highly integrated terahertz transmission module for the D-band with a fully integrated antenna, terahertz transmission modules based on photonics and transmission techniques for mobile terahertz connections. These key components will be integrated into a demonstrator that will serve as a proof-of-concept for the feasibility and performance of terahertz communications for mobile use. In addition, software modules for a flexible 6G core network and fully integrated solutions for localization will be developed and integrated into a prototype test bed demonstrator for the 6G architecture. Another goal is to develop principles, standards, definitions and guidelines for the 6G rollout expected in 2030.

The Fraunhofer Institutes for Integrated Circuits IIS, for Telecommunications, Heinrich-Hertz-Institut, HHI, for Open Communication Systems FOKUS, for Applied Solid State Physics IAF and for Reliability and Microintegration IZM are participating in the project.

Future Proteins – High-quality protein worldwide

The reliable supply of nutritionally valuable proteins for the world's population is the objective of the "Future Proteins" lighthouse project. In this project, the consortium is addressing the problem of "hidden hunger," because the inadequate supply of high-quality protein could be exacerbated by climate change and population growth.

In this lighthouse project, the partner institutes are developing closed, sustainable cultivation systems to produce proteins with optimized nutritional profiles and the highest consumer acceptance possible. The consortium is focusing on particularly valuable alternative protein sources, such as selected plants (wheatgrass, alfalfa, the development of reduced-solanine potatoes), insects (meal worms), filamentous fungi (club fungi such as pleurotus or shiitake), and microalgae (spirulina). All four agricultural systems (plants, insects, fungi, and microalgae) are designed in such a way that they can be used in different locations worldwide and thus contribute to a global supply of protein.

Indoor and vertical farming methods are to be made cost-efficient and sustainable by means of hybrid lighting systems, new plant designs, and automation solutions, all in line with the circular economy principle. For example, in the context of plant cultivation, the research team is focusing on the maximum wavelength-specific use of sunlight through a hybrid lighting system; in the context of insects, they are addressing pathogen monitoring and new hygienic culture modules, together with cost-efficient culture media and optimized process control for insects and fungi; and in the context of algae, they are developing new types of sensors for predictive culture control. The proteins obtained in this way will primarily be used as nutritional enrichment ingredients in the food industry. One of the focus points of the project consists of optimizing the sensory and functional properties of the protein ingredients, with the aim of achieving a broad application spectrum and a high level of consumer acceptance.

The Fraunhofer Institutes for Molecular Biology and Applied Ecology IME, for Process Engineering and Packaging IVV, for Interfacial Engineering and Biotechnology IGB, for Optronics, System Technologies and Image Exploitation IOSB, for Machine Tools and Forming Technology IWU and for Environmental, Safety and Energy Technology UMSICHT are participating in the project.



New proteins for enriching food.

WASTE4FUTURE – From waste to raw material

A sustainable society requires defossilized, climate-neutral industry. The political and regulatory course has been set, for example, through the European Commission's Green Deal, the phase-out of coal in Germany, the associated structural change and carbon dioxide (CO₂) pricing, through the German Packaging Act, which comes into force in 2022, and through the industrial companies aiming to transform the previously linear value creation process into a circular value creation process under the motto of "chemistry 4.0."

Against this backdrop, the WASTE4FUTURE consortium is developing comprehensive solutions for recycling waste products containing plastics – with no loss of carbon. The intention is to use cross-linked processes to maximize the preservation of chemical structures. The central solution is a holistic evaluation model to determine how much energy is needed for the manufacture of raw materials from recycled materials. This will pave the way for technically, environmentally and economically viable methods of recycling various plastic fractions in the future.

Other objectives of the lighthouse project include a hybrid sensor for the identification and characterization of materials with a real-time algorithm, developments in material and chemical recycling (solvolysis, pyrolysis and gasification technologies), in sensor-based sorting technology including digital twinning, in new types of compatibilizers for polymers manufactured through direct synthesis with CO₂, and in high-throughput development of recyclate formulations. One focus area relates to the recycling of long-lasting plastic waste. The WASTE4FUTURE lighthouse project will complement and synergize with the Fraunhofer Cluster of Excellence Circular Plastics Economy.

The Fraunhofer Institutes for Microstructure of Materials and Systems IMWS and for Nondestructive Testing IZFP, the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS, the Fraunhofer Institutes for Optonics, System Technologies and Image Exploitation IOSB, for High

Frequency Physics and Radar Techniques FHR, for Structural Durability and System Reliability LBF and for Process Engineering and Packaging IVV are participating in the project.

ShaPID – Green Deal for the chemical industry

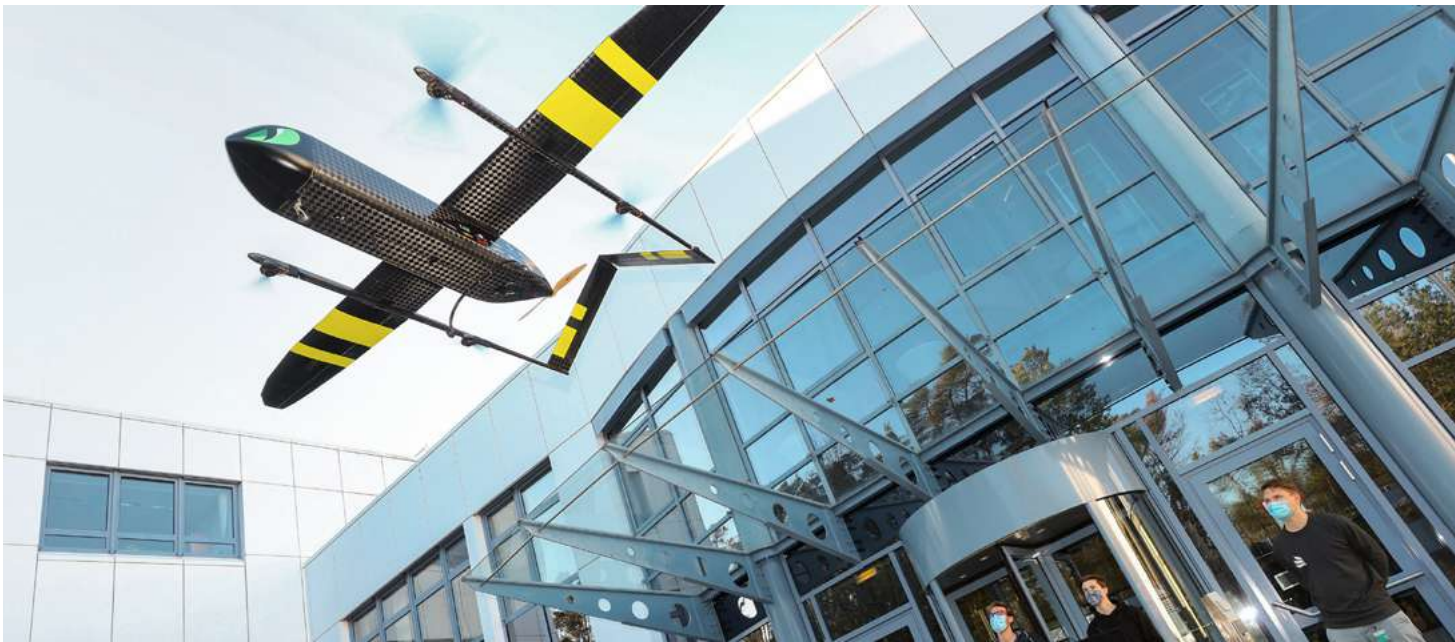
The "ShaPID – Shaping the Future of Green Chemistry" lighthouse project aims to show that sustainable green chemistry is achievable through innovations in the areas of process intensification and digitization. In this way, the consortium is supporting the chemical industry in its efforts to transition to defossilized production processes and a circular, greenhouse-gas-neutral process for converting materials and energy. The project addresses the global challenges of climate protection and energy and resource efficiency.

The project partners are developing new technologies, particularly for green catalysis technology, process engineering, process intelligence and process implementation. They are focusing on synthesis, reaction and catalysis technology, process engineering, modeling, simulation and process optimization as well as digitalization. Among other things, the partners are conducting research on electrocatalytic/biocatalytic process cascades for monomers and polymers using CO₂ as a raw material, and on the production of olefin monomer units from renewable raw materials. All development work is guided by the internationally recognized "12 Principles of Green Chemistry."

The aim is to prove market relevance using demonstration processes such as green plastics, green monomers, and efficient building blocks (production of agricultural and pharmaceutical intermediate products). A Fraunhofer green, efficient chemistry technology platform will be established for this purpose. In addition, a sustainability analysis is being developed that allows companies to quickly and clearly assess new technologies and processes. This will provide the chemical industry and cooperating sectors, such as plant engineering or measurement, control and regulation technology, with targeted support for the transition to green products and processes.



Waste materials are raw materials: The circular principle makes sense both economically and ecologically.



The Fraunhofer Institutes for Chemical Technology ICT, for Applied Polymer Research IAP, for Factory Operation and Automation IFF, for Interfacial Engineering and Biotechnology IGB, for Molecular Biology and Applied Ecology IME, for Microengineering and Microsystems IMM, for Silicate Research ISC, for Industrial Mathematics ITWM and for Environmental, Safety and Energy Technology UMSICHT are participating in the project.

ALBACOPTER – Vertical glider experiment

Air transport in urban environments could offer a solution to ever-increasing volumes of traffic and help overcome the associated social, economic, and environmental impacts. As air traffic goes through a period of upheaval, the ALBACOPTER consortium intends to position itself on the market for autonomous VTOL (vertical take-off and landing) systems early on with their experimental platform. Drone-based application scenarios in urban areas present exceptionally difficult challenges in terms of flight safety, economic efficiency, and environmental compatibility.

Among other things, the project partners aim to improve flight safety using AI-based monitoring of the environment, structure and functioning of the vehicle, increase the

sustainability of the transporter and transport boxes, achieve better energy efficiency, and reduce the net mass of the airborne device, including the battery system. To allow the diverse range of airborne device concepts to be represented, a digital twin is being built in the form of a modular open-source simulation platform. In addition to helicopters and conventional fixed-wing aircraft, hybrid copter-gliders in the form of swing-wing aircraft, gyrocopters or even multicopters with tilt rotors or extendable wings are becoming established. ALBACOPTER is an experimental VTOL glider and will be used to develop and test all these different system concepts.

The system design for the ALBACOPTER is initially oriented toward the requirements for a drone-based just-in-time logistics network for urban and rural areas (distances of up to 200 kilometers with a payload of up to 200 kilograms), as drones from Amazon and DPD have already been approved for testing. Propulsion method design will be adapted depending on the intended use of the VTOL glider.

The Fraunhofer Institutes for Transportation and Infrastructure Systems IVI, for Structural Durability and System Reliability LBF, for Chemical Technology ICT, for Optronics, System Technologies and Image Exploitation IOSB, for Mechatronic Systems Design IEM and for Microelectronic Circuits and Systems IMS are participating in the project.

ALBACOPTER is an experimental glider and will be used to develop and test various system concepts.

Projects and results 2020

Hydrogen Technologies

Green hydrogen on a large scale

The Fraunhofer electrolysis platform Leuna ELP will go into operation in 2021. It will demonstrate on a large scale how hydrogen produced using electricity generated from renewable energies can be used for the production of basic chemicals and fuels. Up to 5 megawatts of power input are available for testing various types of electrolysis systems. The green hydrogen is fed into the pipeline system operated by the cooperation partner Linde. It will be the first electrolysis test facility in Germany that is fully integrated into a material flow network of the chemical industry.

Until now, the approximately 100,000 standard cubic meters of hydrogen required per hour by the chemical region in central Germany have been obtained conventionally from fossil natural gas. This makes the chemical region not only one of the largest users of hydrogen, but also one of the largest emitters of CO₂. With the ELP, hydrogen can be produced by means of electrolysis in an environmentally friendly and climate-neutral way, in so far as the power for the electrolyzers comes from renewable energy sources.

The researchers are developing various electrolyzers further through testing, both for operation at low temperatures of up to 80°C and for steam electrolysis. Real operating conditions from photovoltaic systems and wind farms are simulated to assist in designing and estimating costs for the systems. The effects of the fluctuating operation on the durability of the components and the downstream processes are then explored.

The manufacture of green hydrogen or synthesis gas on the ELP is linked directly to the scaling platform Hy2Chem, which is used to produce basic chemicals and fuel from the generated hydrogen and CO₂. In terms of building regional industrial power,

Hy2Chem offers great potential for the structural change that will occur after the fossil fuel phase-out. The scaling platform is coordinated by the Fraunhofer Center for Chemical-Biotechnological Processes CBP and the Fraunhofer Institute for Microstructure of Materials and Systems IMWS.

The hydrogen factory of the future

With its hydrogen factory of the future, the Fraunhofer Institute for Factory Operation and Automation IFF is developing a concept for the decentralized, modular production and distribution of green hydrogen for industry, business and transportation.

Power-to-X technologies, such as electrolysis, can be used to convert electricity sourced from renewables into hydrogen, store it and feed it into the gas grid. The raw material can be used as fuel or as basic chemicals for industrial applications in various sectors, e.g. for fuel-cell-powered vans and forklifts in industrial and business parks.



Groundbreaking ceremony in Leuna: "Green" hydrogen will act as a stimulus for a sustainable chemical industry.

The additional production of hydrogen will increase the efficiency of biogas plants in the future.



It is not possible to use sun or wind energy to obtain hydrogen through electrolysis in every location. The hydrogen factory provides a key element here through a kind of biogas plant. Plans are currently being drawn up for a pilot plant in the Magdeburg region that will produce hydrogen through fermentation. A team of scientists is working together with MicroPro GmbH and Streicher Anlagenbau GmbH & Co. KG on a special fermentation process (the HyPerFerMent I project) to produce hydrogen from organic waste using microorganisms.

Another module involves a mobile system for demand-driven transport and the distribution of hydrogen for various applications. As part of the small distribution system "Mobile Modular H₂ Port" – a project funded by the German Federal Ministry of Education and Research – a small trailer for transporting hydrogen is being designed in collaboration with Anleg GmbH. This contains expandable pressure systems with compressors that can be used both to store and dispense hydrogen.

The oxygen produced during electrolysis is also used in the hydrogen factory, e.g. for welding processes, for ozonation in sewage treatment plants or for desulfurizing biogas plants in agriculture. The projects "2020 Energy Region Staßfurt" and "Energy Region Ostharz" contributed significantly to the concept of the hydrogen factory.

A special hydrogen-resistant steel coating made of Ti₂AlN.

Special coating protects steel from hydrogen

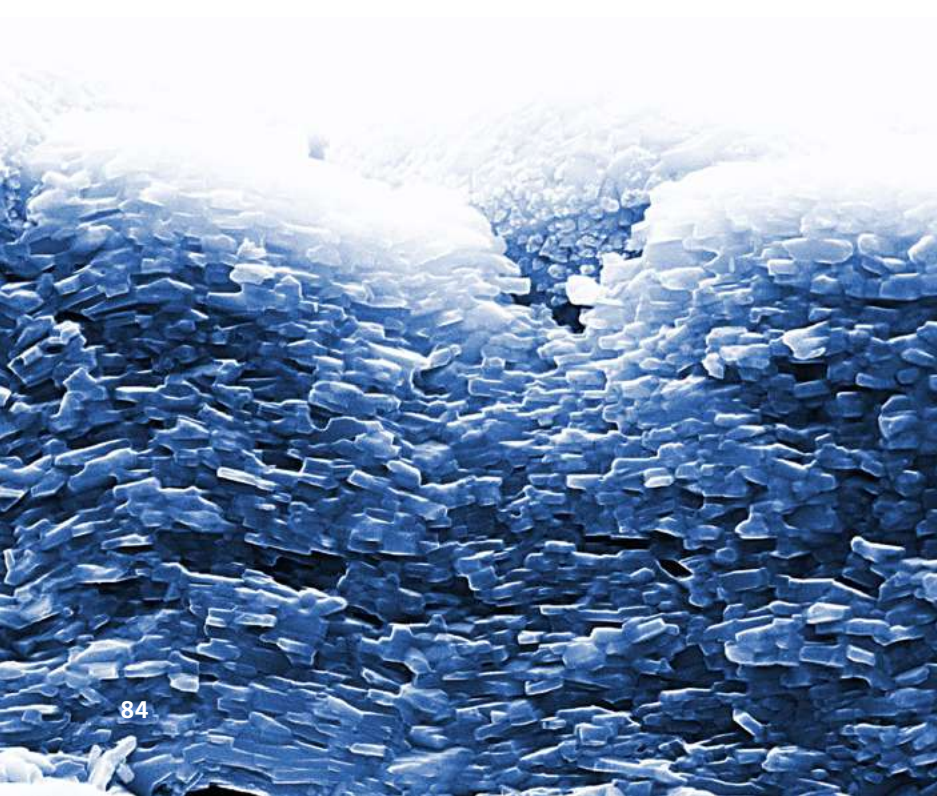
The transport and burning of hydrogen requires new types of safety solutions to prevent metal from becoming brittle due to hydrogen exposure, especially at high temperatures. Researchers at the Fraunhofer Institute for Mechanics of Materials IWM, MikroTribologie Centrum µTC, are developing a robust coating.

From MAX-phase materials, which have been the subject of around fifteen years of research and combine characteristics of ceramics and metals, they have succeeded in producing and characterizing layers that are only a few micrometers thick. These materials are produced from layers of aluminum nitride and titanium on a steel surface using physical vapor deposition (PVD). This sandwich structure is then heated to form a MAX-phase layer of titanium, aluminum and nitrogen (Ti₂AlN). The key to the success of this precision procedure is closely packing the crystal platelets that are formed, like bricks in a wall. The research team also simulated the operating conditions of an intensively heated gas turbine, which gave rise to a thin layer of a special aluminum oxide on the top side of the coating (α-Al₂O₃). It considerably increases the protective layer's barrier effect against hydrogen.

The development of a test rig allowed the comparison of uncoated steels with MAX-phase-coated steels. This enabled the research team at Fraunhofer IWM to precisely quantify the penetration of hydrogen and to determine the permeation reduction factor (PRF) as a standard for measuring the barrier effect. The results were that coated and heated steels with a α-Al₂O₃ layer withstand hydrogen around 3500 times better than untreated steel.

Producing natural gas from carbon dioxide

Experts in reforming and power-to-gas processes at the Fraunhofer Institute for Microengineering and Microsystems IMM are developing a process for converting carbon dioxide into natural gas by adding green



hydrogen. The non-fossil natural gas produced using green hydrogen is ideal as a storage medium for volatile renewable energies, such as solar power or wind power, due to the well-established gas grid infrastructure.

For this process, known as the methanation of carbon dioxide, researchers are tackling a number of challenges, with a particular focus on biogas plants. In particular, special catalysts had to be developed to make the process more robust. When using carbon dioxide from biogas plants, the catalysts had to be stabilized to prevent sulfur poisoning. Specifically for this reforming process, the team of scientists is developing long-lasting catalysts that are resistant to poisoning and coking.

For the reactor technology, the researchers applied their tried-and-tested microstructured reactor approach with integrated cooling. They opted for a new two-stage model, consisting of a monolithic reactor coated with a high-temperature-resistant catalyst and downstream, an oil-cooled heat exchanger reactor. It is operated at a much lower temperature, which allows it to take advantage of the increasing conversion to methane in these conditions. A conversion rate of over 97 percent of the supplied carbon dioxide could thus be achieved. The feasibility of the concept was verified by means of an initial pilot plant, which will be followed by a larger system that is connected to a biogas plant.

Widespread hydrogen availability

The objective of the H2PROGRESS and POWERPASTE projects is to make hydrogen reliably available for various applications on a wide scale, without dependence on a high-pressure supply system with costly infrastructure. In the H2PROGRESS project, Siemens and the Dresden branch of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM are developing and testing a new type of fuel cell energy storage system. An initial test setup is expected to deliver one kilowatt of electricity using one oxygen-powered fuel cell. In future, this could be used for air-independent propulsion of underwater vehicles. In the POWERPASTE project, Fraunhofer

IFAM is working together with Vitesco, AVA Maschinen Service GmbH, EMEC Prototyping, the hydrogen and fuel cell center ZBT and the university of Magdeburg to develop a prototype power generator for lightweight vehicles.

The hydrogen is provided in the form of a magnesium-hydride-based solid, rather than as a gas or extremely cold liquid. This is possible using POWERPASTE, which was developed and patented in Dresden in 2016. The paste contains approximately 70 percent by volume magnesium hydride powder. The hydrogen is released immediately when water is added at room temperature. The energy content is more than ten times that of modern lithium-ion batteries. It is far superior to conventional batteries particularly in terms of service life, energy storage density, self-discharge rate, operating temperature range and recharging speed. Production of the paste on a pilot scale at the Fraunhofer Project Center for Energy Storage and Management Systems ZESS is scheduled to start in 2021. The POWERPASTE should then be available as a changeable cartridge system, among other formats.

With the combined energy systems from POWERPASTE and fuel cells, the projects mentioned above address not only the questions of safety and grid independence, but also a significant reduction in power generation costs when using hydrogen. Future areas of application include back-up energy systems, portable or mobile electronic devices, sensors, probes, buoys, light signals, electric scooters, drones and camping equipment. H2PROGRESS is part of the HYPOS innovation project funded by the German Federal Ministry of Education and Research, and will run up to the end of 2021. The POWERPASTE project will run until October 31, 2023 and is funded by the German Federal Ministry for Economic Affairs and Energy.



*Top:
Long-lasting, poisoning- and
coking-resistant catalyst
for methanation of carbon
dioxide.*

*Bottom: :
The patented POWERPASTE is
expected to be available as a
changeable cartridge system
as early as 2021.*

Resource Efficiency and Climate Technologies

Joseph von Fraunhofer Prize **The CO₂-free-transportation revolution**

DC/DC converters are indispensable for the defossilization of the transport industry. Small, highly efficient and cost-effective voltage converters are needed for hydrogen-powered fuel cell vehicles, for electric commercial vehicles that use overhead lines and for the rail transport, shipping and aviation industries.

DC/DC converters modulate the volatile voltage level of fuel cells to suit the propulsion method. Dr.-Ing. Bernd Eckardt and Dr.-Ing. Stefan Matlok from the Fraunhofer Institute for Integrated Systems and Device Technology IISB succeeded in overcoming the conflict between high efficiency and minimum physical size that had previously caused problems. The two experts defied the conventional wisdom that high switching

frequencies cause losses and greater thermal discharge by investigating, analyzing and simulating the effects together rather than individually.

As early as in 2014, a new kind of capacitor component integrated directly in silicon ("snubber module") was developed at Fraunhofer IISB. This was built into power modules with ultra-modern semiconductor field-effect transistors made of gallium nitride or silicon carbide components. This combination was used to demonstrate "zero over-voltage switching" in 2018. Despite a higher switching frequency and smaller size, this design can achieve a previously unattained efficiency of 99 percent. Through mechatronic 3D integration, supported by thermal simulation and the converter's digital modeling method ("valley switching"), the researchers managed to optimize the power density values even more. Its use has already been

Dr.-Ing. Bernd Eckardt (right) and Dr.-Ing. Stefan Matlok from Fraunhofer IISB are using their expertise in DC/DC converters to develop innovations for fuel cell vehicles.



demonstrated in fleet testing by VW and Audi, in the fuel cell racing car GreenGT, and in extreme temperature tests in Southern Spain and in the polar circle. The spin-off HABTIS GmbH is being set up to bring these research results into commercial application.

The most compact and most efficient DC/DC converter in the world is a key component for the hydrogen fuel cell power train. Dr.-Ing. Bernd Eckardt and Dr.-Ing. Stefan Matlok from Fraunhofer IISB were awarded the Joseph von Fraunhofer Prize for this development.

Joseph von Fraunhofer Prize | Innovation award from the European Association for Research and Technology Organisation EARTO **Reinventing fire-resistant glass**

Fire-resistant glazing usually contains a gel that contains carcinogenic acrylamide. But the fire-resistant glazing on the Global Tower being built in Frankfurt City does not, thanks to a new type of fire-resistant glazing from the VITRAFIRE® product line produced by the family-owned company Hörmann KG Glasstechnik. This is based on the research work carried out by Dr. Holger Wack and Damian Hintemann from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. Together with Thomas Baus from Hörmann KG Glasstechnik, the chemical engineers developed a hydrogel based on a polymerized monomer as well as a new sustainable production process.

One of the milestones in the production process is an injection valve – patent pending – for mixing two reactive, low-viscosity liquid streams when filling the gap between two panes of glass with the new type of gel. The know-how for filling the gap without bubbles and the resulting streak-free reaction of the monomer solution to form a highly transparent hydrogel was applied to a digitalized, partly automated production line. This allows a leaner, significantly more resource-efficient production process. For example, the production of fire-resistant glass doors generates just 20 kilograms of process waste a day – instead of around 150 kilograms as with previous production methods. In the event of a fire,

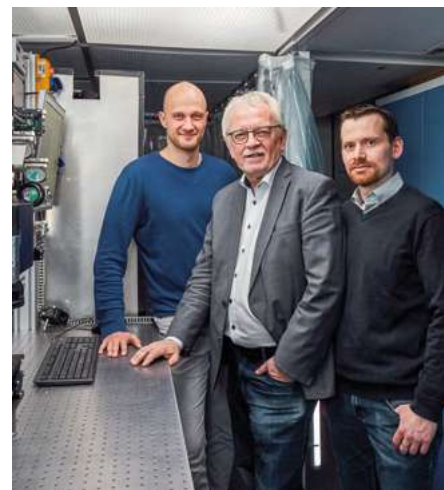
the glazing withstands flames and heat over 1000°C for up to the required 120 minutes.

The jury responsible for awarding the Joseph von Fraunhofer Prize was impressed with the way in which the research results had been implemented in practice. The process engineering developments were taken from the laboratory to practical application in just four years. And what's more, the family-run company Hörmann KG set up a subsidiary and a new location, Hörmann KG Glasstechnik, for the new production line of the certified VITRAFIRE® fire-resistant glass.

Stifterverband Science Prize **Sustainable structuring of large surfaces**

The research results of an industrial consortium for laser structuring using ultrashort pulse lasers allow for efficiency on multiple levels. Large components, such as steel embossing rollers, can thus be produced quickly for the first time. The new process, which has been developed chiefly by the Fraunhofer Institute for Laser Technology ILT, enables economically profitable and at the same time, more sustainable production. This is because the previous, environmentally harmful method of manufacturing many components by means of multiple wet chemical etching processes can now be done away with in many cases.

This required technological breakthroughs: Instead of directing the pulsed laser beam across the surface just as a single beam, the pulse energy is split into many partial beams with identical power, which are then directed across the component for parallel processing. An optical system was also developed for switching the partial beams on and off individually and flexibly, and for modulating their power. This makes it possible to produce any surface structures in a short time. The partners succeeded in shifting the detail resolution into the nanometer range and at the same time, increasing the processing speed by a factor of 10. The basis for this is a new ultrashort pulse laser that emits picosecond pulses and allows homogeneous diffractive beam splitting. The linking of the project partners' different areas



*Top:
A new fire-resistant glazing
process makes it easier to
manufacture and uses no toxic
substances.*

*Bottom:
Together with their industrial
partners, Prof. Dr.-Ing. Arnold
Gillner (center), Dipl.-Phys.
Martin Reininghaus (left) and
Dr.-Ing. Johannes Finger from
Fraunhofer ILT developed an
innovative process for econom-
ically viable, yet sustainable
structuring of embossing rollers.
They won the Stifterverband
Science Prize for their work.*

According to the German Federal Environment Agency, 26 percent of total energy consumption in 2018 went to heating rooms in buildings.

of expertise was the core of the MultiSurf project funded by the German Federal Ministry of Education and Research.

The components were integrated into a new machine system developed by the company Schepers, with ablation rates of up to 100 cubic millimeters per minute. In addition to embossing and pressure rollers, plastic components for cars or light guide components, antimicrobial surfaces for medical products, anti-icing components on wind turbines or microstructures for the aerospace industry could therefore be manufactured in order to reduce consumption.

For their ground-breaking solutions, Prof. Dr.-Ing. Arnold Gillner, Dipl.-Phys. Martin Reininghaus and Dr.-Ing. Johannes Finger from Fraunhofer ILT, together with Dr. Stephan Brüning from Schepers GmbH & Co. KG, Dr. Gerald Jenke from Matthews International GmbH, Dr. Keming Du from EdgeWave GmbH Innovative Laser Solutions, and Dr. Manfred Jarczyński from LIMO GmbH, were awarded the Stifterverband Science Prize 2020.

Bioinspired chemistry

Today, plastics and speciality chemicals are indispensable in many areas. Until now, fossil sources were mostly used for their basic components. Henkel AG & Co. KGaA and the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB are adopting a new approach by using keratin as a biopolymer raw material. The use of feathers as a bio-based raw material in industrial applications is still largely undeveloped. Most of the feathers generated every year in poultry farms in Europe are converted into animal feed or disposed of as waste. But the keratin they contain could be used as the basis for oligomer fractions.

Researchers at the Straubing branch of Fraunhofer IGB are currently investigating how feather waste can be harnessed for speciality chemicals: At present, shortened polymers – oligomers – are obtained through a hydrolysis process, in order to bring the protein chains into the solution and form them into a network during subsequent use. After the

first manufacturing protocols have been developed in Straubing, the production of the oligomer fractions will take place on a large scale at the Fraunhofer Center for Chemical-Biotechnological Processes CBP in Leuna. Henkel is planning future applications for this technology in the plastics industry.

The KERAbond project for obtaining speciality chemicals from tailor-made keratin proteins containing polythiol will be funded by the German Federal Ministry for Food and Agriculture based on a resolution passed by the German Bundestag. Henkel AG & Co. KGaA will coordinate the project.

Innovation district in Bochum-Weitmar

City districts offer the ideal conditions for a successful, local implementation of the energy transition, as they bring together requirements in electricity, heat and transport. And a “heating transition” is unavoidable. According to the German Federal Environment Agency, 26 percent of total energy consumption in 2018 went to heating rooms in buildings. For this reason, a consortium for the Bochum-Weitmar district is developing methods for identifying and implementing ideal solutions at district level as part of the “Open District Hub” initiative. The goal is to use largely renewable energies and combine them with appropriate redevelopment measures. Vonovia SE, Ampeers Energy GmbH as well as the Fraunhofer Institutes for Applied Information Technology FIT, for Optronics, System Technologies and Image Exploitation IOSB and for Environmental, Safety and Energy Technology UMSICHT are participating in the initiative.

In Germany, redevelopment measures often involve existing city districts comprising apartment buildings from the mid-20th century that urgently require energy redevelopments. Integrated solutions for districts and innovative business models, such as storing energy at district level and transport services, can unlock synergies across buildings and help to achieve a reliable, economically and ecologically efficient power supply system.



Project partners walking through the district in Bochum-Weitmar.

This involves harnessing the potential offered by interlinking the electricity, heat and transport sectors – from an energy and economic perspective as well as from an information and communication technology perspective. In designing business models, the researchers are also taking into account an analysis of user preferences and user behavior. They are developing an integrated district planning system, a digital market platform and a self-learning energy management system. These instruments are supported by an interoperable, scalable middleware platform and an automatic learning process. The tools developed in this way are already being used in several districts of Bochum-Weitmar as part of the building measures in order to demonstrate integrated planning as well as a reliable and economically and ecologically efficient power supply.

Plastic camshaft module reduces CO₂ emissions

Lightweight design helps lower CO₂ emissions. Camshaft modules, which are a key component of power trains, were previously made from aluminum. Now, a research team from the Fraunhofer Institute for Chemical Technology ICT, in collaboration with their partners, has succeeded in manufacturing a functional demonstrator from fiber-reinforced thermoset polymers. For the plastic, the consortium opted for high-strength, fiber-reinforced thermoset polymers. These are well able to withstand high temperatures and mechanical and chemical stresses such as those caused by synthetic motor oils and coolants. The scientists at Fraunhofer ICT contributed their know-how as regards material and process requirements for the geometric design of the components in particular.

Even before the manufacturing process, simulation calculations were used to help design the prototype: Although the stiffness of the thermoset polymer is only a quarter of that of aluminum, the measures adopted by the team in construction enabled them to comply with the maximum allowable deformation. Aluminum inserts at the highly stressed points of the camshaft bearings ensure the necessary degree of safety. After 600 hours

of testing on the engine test stand, the lightweight design element demonstrated flawless functionality.

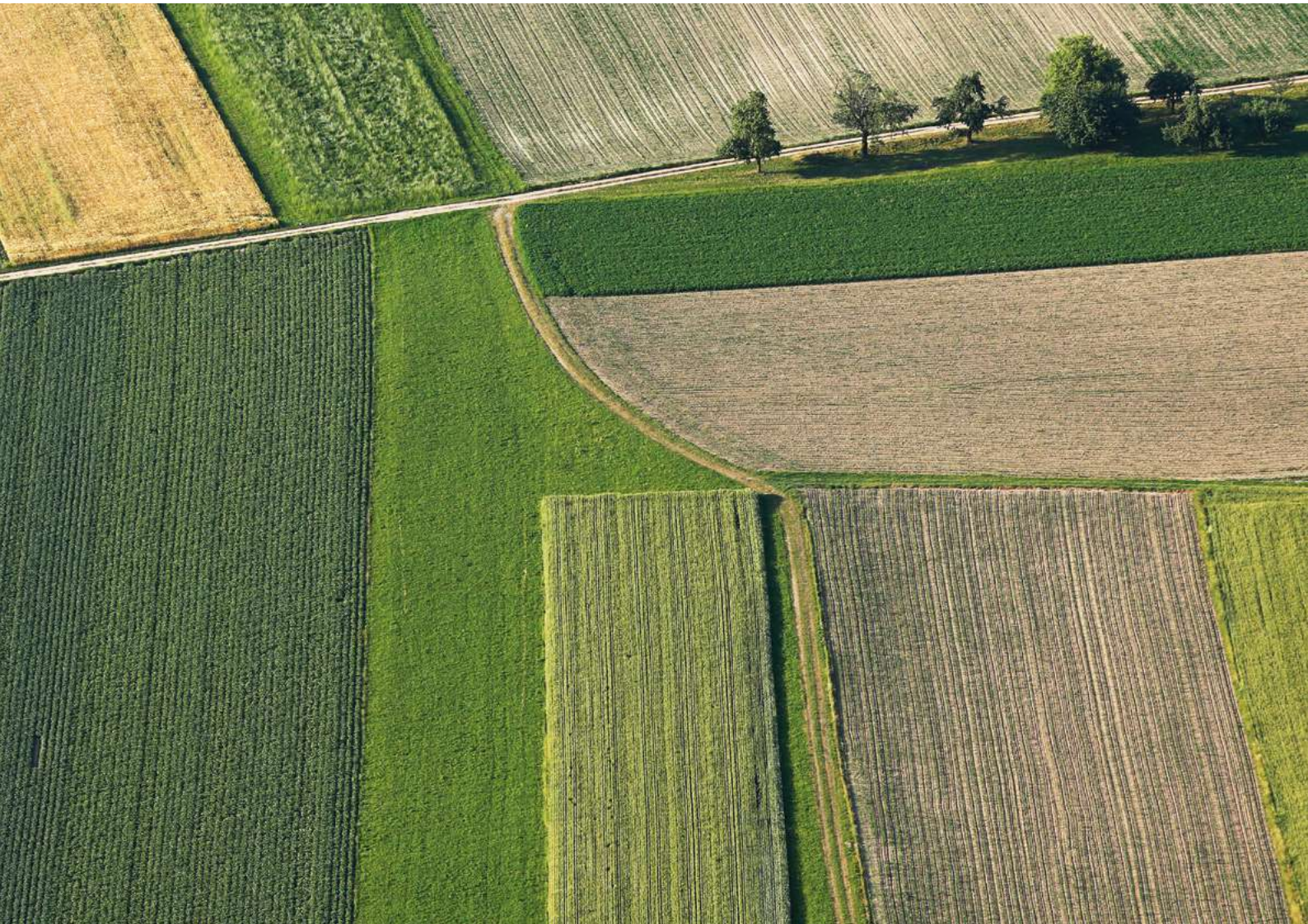
The camshaft module made primarily from plastic not only has a lower CO₂ footprint during manufacture, but also has other advantages over the aluminum castings that have been until this point. The component is injection-molded to near-net-shape using fiber-reinforced thermoset polymers and reduces assembly time in the engine manufacturing plant. This lowers production costs both during finishing and installation. Additionally, the service life of thermoset polymer injection molds is higher than that of aluminum high-pressure die cast molds. The plastic also provides insulation and good performance in relation to the competitive factor of noise, vibration and harshness, the acoustic and mechanical vibrations of the component.

The lightweight module was realized as part of a project funded by the German Federal Ministry for Economic Affairs and Energy. Fraunhofer ICT collaborated on this module with the MAHLE Group and associated partners Daimler AG, SBHPP/Vyncolit NV and Georges Pernoud.



Camshaft module made primarily from plastic.

Bioeconomy



X-raying entire fields of wheat

Continuing to feed the growing world population with an agricultural sector affected by climate change is a pressing global challenge. To resolve this problem, a team at the Development Center X-Ray Technology EZRT at the Fraunhofer Institute for Integrated Circuits IIS intends to use its research to make plants fit for climate change.

Since 2013, a research group has been working on X-raying plants. An automated computer tomography system allows them to record crop heat stress and yields. This enables plant breeders to select crops that are particularly resistant. What started with X-raying single potatoes in flowerpots has now been scaled up: X-ray modules developed by Fraunhofer EZRT are used for growing potatoes in China, for increasing corn yields in the U.S. and for heat-resistant wheat in Australia. By repeatedly X-raying wheat plants, for example, breeders can monitor the growth of grains in the ears and identify how individual varieties react to heat or drought while they are still in the field. A mobile X-ray system that allows entire fields to be X-rayed has now been developed in the form of the four-wheeled vehicle DeBiFix.

Rethink plastic

In spring 2020, the EU-funded project FlexFunction2Sustain was launched with the aim of increasing the share of sustainable and smart plastic and paper products from European production. Materials based on plastic and paper are used in food and pharmaceutical packaging, medical products, furniture surfaces or membrane-based filter systems, to name a few examples. They are often produced from fossil raw materials. Many of the products contain composite or multi-layer materials that are neither fully recyclable nor biodegradable.

New, bio-based, biodegradable polymer formulations can make an important contribution to reducing levels of plastic waste worldwide. This has resulted in new and adapted product designs, e.g. for packaging. Depending on the application, various functional properties are required, from resistance to chemicals and corrosive gases such as steam and oxygen through anti-microbial and anti-viral surfaces right up to electrically conductive films for smart packaging and plastic-based sensors. Nanotechnologies make these properties possible. The 19 partners in the "EU Horizon 2020" project FlexFunction-2Sustain (GA No. 862156) are focusing on recyclable or compostable food and cosmetic packaging, membranes for water filters and

diagnostics, innovative and smart plastic surfaces in the automotive industry as well as biodegradable security and fraud protection labels.

The consortium covers the entire technical spectrum of nano-functionalization techniques available for plastic and paper surfaces – from atmospheric pressure and vacuum coating processes through nano-structuring to the integration of flexible electronics. Pilot systems for manufacturing films and verifying recyclability and biodegradability as well as accredited test labs for food contact and anti-microbial and anti-viral properties round off the consortium's portfolio. With an Open Innovation Test Bed, the project partners support start-ups and SMEs in particular throughout the entire innovation process. An Open Innovation Test Bed is a network of research and development service providers, business consultants and investors that offers its combined services via one general contractor ("single entry point"). The goal is to increase the market share of European industries in sustainable and smart plastic and paper products. The project coordinator of the EU consortium is the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP in Dresden. The Fraunhofer Institutes for Applied Polymer Research IAP and for Process Engineering and Packaging IVV are participating in the project.

Green methanol on a miniplant scale

Methanol is already one of the most essential basic chemicals in the world today. It will gain importance as a chemical energy carrier and fuel additive for the energy and transport transition. Conventional production processes are based on fossil raw materials and cause high CO₂ emissions. In contrast, methanol synthesis based on Power-to-X – the production of methanol from hydrogen and CO₂ – makes it possible to bind greenhouse gas and recycle it.

In a miniplant system (production output 1 kg/h) at the Fraunhofer Institute for Solar Energy Systems ISE, hydrogen and CO₂ are converted to methanol in a continuous process. In this process, heat is released and



*Top:
A phenotyping robot is
deployed in the field.*

*Bottom:
Innovations for sustainable
plastic and paper products
need to be promoted and
must be more quickly imple-
mented as market-ready
products.*



Scale-down miniplant for researching methanol synthesis at Fraunhofer ISE.

water is produced as a by-product. The operation of the technology platform is designed to resolve issues in relation to implementation on an industrial scale in the future. For example, the researchers are investigating how to reduce accelerated catalyst aging due to the high CO₂ content in the synthesis gas from biorefineries, which results in lower chemical yields.

Temporal and spatial high-resolution measurement technology is used to assist the researchers. The knowledge gained in this way will be linked to the existing dynamic simulation platform at Fraunhofer ISE. This enables the precise analysis of the effects of load changes as they would occur in real industrial plants in the future. This in turn generates valuable data that can be applied to obtaining green methanol. Other partners in the "Power-to-Methanol – Green Methanol" project funded by the German Federal Ministry for Economic Affairs and Energy and run by DECHEMA e.V. include CropEnergies AG, Clariant, thyssenkrupp Industrial Solutions AG, the TU Bergakademie Freiberg, the Fraunhofer Institutes for Interfacial Engineering and Biotechnology IGB and for Environmental, Safety and Energy Technology UMSICHT.

An alternative to crude oil

A research team from the Fraunhofer-Gesellschaft and the Technical University of Munich (TUM) led by Prof. Dr. Volker Sieber has succeeded in developing a new family of polyamides from a by-product of cellulose production.

Polyamides are important plastics that are used in a wide range of products, from ski bindings to cars and items of clothing. Commercially, they have been made predominantly from crude oil up until now; "green" alternatives, such as polyamides from castor oil, are few. Bio-based compounds are often significantly more expensive to produce and as a result they have so far only been able to penetrate the market if they have had particular properties.

The research group used (+)-3-carene as the biogenic starting material. This can be distilled at a high purity and comparatively low cost from turpentine oil, which is produced as a by-product in the cellulose industry. The compound (+)-3-carene is made up of two rings which are fused to one another. The chemists at the TUM and the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB in Straubing modified one of the rings in such a way that instead of the linear polymer chain of a normal polyamide, it resulted in a chain with many small rings and other side groups. This gives the polymer new properties, such as softening at higher temperatures than competing crude oil products, for example. In addition, the new compounds can be produced in both a transparent and a partially crystalline form, which means there is a much wider range of possible applications from the one starting substance.

The lasting effect is that turpentine oil, which up to this point was simply burned up in cellulose factories, can now be converted into a valuable starting material for plastics. In addition, it is not competing against food production. The chemists at Fraunhofer IGB in Straubing have optimized the overall yield of the process. Their findings were published in "Nature Communications" (DOI: 10.1038/s41467-020-14361-6) at the beginning of 2020.

Sustainable nutrients for agriculture

Agriculture requires significant amounts of nitrogen and phosphorus to ensure long-term nutrition and yields. Until now, mineral fertilizers containing these nutrients have mostly been produced chemically or extracted from mines, processed and transported on a global scale: an energy- and cost-intensive production route. At the same time, large quantities of nutrients accumulate during wastewater treatment, animal husbandry and in biogas plants. As sewage sludge, slurry, dung or fermentation products, they cause significant environmental problems due to their local concentration. Their nitrous oxide and methane emissions are harmful to the climate, while contaminants in sewage sludge, such as heavy metals or pharmaceutical residues, pollute soil and water.

In order to recycle nutrients from organic residues for agriculture and reduce the negative environmental effects, a consortium made up of companies and research institutions in central Germany is developing the requisite technologies. The Fraunhofer Institute for Ceramic Technologies and Systems IKTS has achieved some initial success in the ongoing funding project abonoCARE®: Special ceramic membrane contactors draw ammoniacal nitrogen directly out of agricultural fermentation products and condensates. The ammonia sulphate solution (ASL) obtained in this way is approved for use as fertilizer. The contactors are used in the form of a tube system or as a bundle of capillaries and can withstand very harsh conditions. Ceramics also help with the combustion of sewage sludge containing high levels of heavy metals: When used together with an additive, high-temperature and chemical-resistant hot gas filters made from silicon carbide make it possible to separate the heavy metals from the combustion ash. The ash can then safely be further processed into fertilizer products.

The abonoCARE® project is funded by a structural change program (growth core) of the German Federal Ministry of Education and Research. The consortium consists of nine companies and six research institutions, with scientific coordination falling to Fraunhofer IKTS.



Fractionated fertilizer product and end products such as fertilizer granulate, liquid fertilizer and litter pellets.

Special ceramic membrane contactors draw ammoniacal nitrogen directly out of agricultural fermentation products and condensates. The ammonia sulphate solution (ASL) obtained in this way is approved for use as fertilizer.

Digital Healthcare

Healing with electronics instead of medications

The use of miniaturized electronics in the form of micro-implants instead of pharmaceutical products, is known as electroceuticals in research contexts. This technique could be used to treat common chronic diseases and illnesses, such as asthma, diabetes, Parkinson's disease, migraines, rheumatism, high blood pressure or incontinence. This requires that the functioning of the areas of the body affected by the illness or disease must be receptive to electrostimulation.

A group at the Fraunhofer Institute for Reliability and Microintegration IZM, together with the Delft University of Technology and teams of scientists in Europe, the U.S. and Asia, are working on electroceuticals for urinary incontinence among other things. For example, patients suffering from urinary incontinence could receive a bioelectronic implant that continually measures their bladder volume and sends a message when they need to use the toilet. It could also use high-frequency stimulation of the damaged nerve to stop the bladder from emptying unintentionally.

Challenges lie in the development of miniature, flexible and durable electroceuticals. To record and process data in the human body, this data must be sent outside the body wirelessly, which is a challenge because embedding implants in organs and bodily fluids is certainly not ideal for transmitting radio signals. The implant must also be recharged wirelessly using ultrasound: Ultrasonic waves stimulate the movement of tiny vibrating bodies in the implant and change its shape. This elastic deformation is converted into power. Miniaturization is necessary for the activation of nerve cells via electrodes so that electric impulses can stimulate physiological responses. Flexible electrodes are

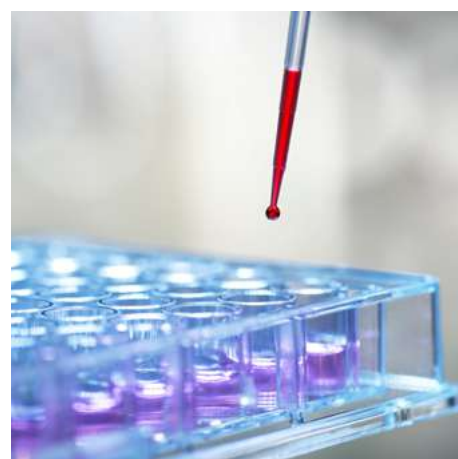
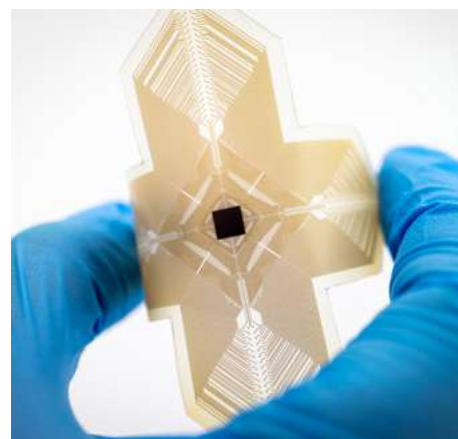
connected to microchips that are 10 micrometers in thickness, to create feedback loops between nerves cells and micro-implants. To prevent rejection reactions in the body, the bioelectronics specialists use materials such as biocompatible polymers, precious metals and silicon. Collaborating partners at the Berlin Center for Digital Transformation are working on data security.

The research team at Fraunhofer IZM is funded by the Fraunhofer Attract program. This enables the Fraunhofer-Gesellschaft to work together with outstanding external scientists who help to bring their ideas to market-readiness.

Treating more heart patients with telemedicine

Telemedical support can make life at home easier for many people with chronic heart failure. Up to now, however, it has not been possible for an individual telemedicine center to care for more than 500 patients. In a project funded by the German Federal Ministry for Economic Affairs and Energy, the Charité – Universitätsmedizin Berlin university hospital is developing a smart system that will allow such centers to care for several thousand cardiological risk patients in the future. It is based on a study carried out by Charité, which confirmed the success of telemedical care for the first time.

For the Telemed5000 project, scientists at the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS are developing acoustic algorithms for the detection of voice changes for example, as this can indicate pulmonary congestion caused by heart failure. The potential applications of artificial intelligence (AI) and the Internet of Things have resulted in a system solution that facilitates the technical aspects of managing large



Top:
Miniaturized electronics in an implant.

Bottom:
Laboratory analytics.



numbers of patients during standard care. The vitals data from patients that is sent to the telemedicine center on a daily basis, from home ECGs for example, is “pre-analyzed.” This helps medical staff when it comes to making decisions.

The institute is supporting the project consortium with the design and technical implementation of a tablet app, which patients can use to make voice recordings, for example. The audio data can be uploaded in encrypted form into Charité’s IT infrastructure and analyzed using an AI web service. A coronavirus study will also be implemented in parallel with the dialysis/ heart failure study. Following their release, intensive care patients could also be provided with telemedical follow-up care using voice characteristics analysis. User-friendliness, respecting data confidentiality and data-protection-compliant information processing are high priorities here.

Partners in Telemed5000 include Charité – Universitätsmedizin Berlin, Fraunhofer IAIS, GETEMED Medizin- und Informationstechnik AG, the Hasso-Plattner Institute of the University of Potsdam and SYNIOS Document & Workflow Management GmbH. There are also associated partners such as the Austrian Institute of Technology – AIT in Vienna, TU Berlin and the German Heart Center Berlin.

Infection protection reporting goes digital

Since June, laboratories have been able to report infection cases electronically to the relevant health authorities, which helped to speed up tracking of SARS-CoV-2 infections. The electronic transmission of information means that protection measures can be introduced promptly in order to interrupt the infection chains. In addition, more complete information can be transmitted than before. The Fraunhofer Institute for Open Communication Systems FOKUS in collaboration with the German Federal Ministry of Health is supporting the Robert Koch Institute in implementing the project.

The electronic reporting of SARS-CoV-2 pathogen detection is the first stage of expansion of the German electronic reporting and information system for infection protection (DEMIS). Its aim is to fundamentally modernize the reporting system in the German Infection Protection Act in the coming months and years, and improve the provision and evaluation of data and cooperation between the health authorities.

To expand DEMIS and maintain its future viability, the messages and their content needed to be flexibly adjustable. To achieve this, the scientists broke new ground in

Telemed5000 uses digital elements to make it easier to manage large numbers of patients during standard care.

system design based on efficient e-health standards. The new standard FHIR (Fast Healthcare Interoperability Resources), for example, is being used in DEMIS to support data exchange between software systems in the healthcare system. A new development in the field of public health services is that the message content will be mapped.

The DEMIS-SARS-CoV-2 project was implemented by the Robert Koch Institute and the German Federal Ministry of Health in cooperation with gematik and Fraunhofer FOKUS.

Improving identification of disseminated tumor cells

Nine out of ten cancer deaths are caused not by the primary tumor, but by secondary tumors. These are single disseminated tumor cells that can be fatal for cancer patients if these "killer cells" metastasize after years.

A study carried out in 2020 used genetic data to research the mechanisms of metastasis and identified approaches for new forms of treatment. The Fraunhofer Institutes for Toxicology and Experimental Medicine ITEM, for Manufacturing Engineering and Automation IPA and for Integrated Circuits IIS participated in the study. To diagnose the onset of metastasis at the molecular and cytological level, the research team used a new method that can be used to examine the entire lymph node, unlike the standard frozen section procedure whereby the tissue between the slices is disregarded. The cells in the lymph node are separated using a tissue grinder, stained using dye and scanned automatically. A high-sensitivity AI-based imaging technique then identifies any cancer cells. Using this method, tumor cells were detected in half of the examined tissue samples, while cancer cells were found in just 15 to 20 percent of the samples using the conventional frozen section procedure. The new method also includes a genetic analysis that shows whether the disseminated tumor cells are already showing different properties from the primary tumor or have become more aggressive and whether a different treatment from that used for the primary tumor may be necessary.

The objective of the 40-person Fraunhofer research team is to find the right metastasis-prevention drug for all patients. To achieve this, a technology that is already approved for the analysis of large numbers of tumors will be adapted for single-cell analysis, so that cells can be tested for 450 cancer-specific mutations for which drugs are already available. The Regensburg branch of Fraunhofer ITEM is working with various companies that want to transfer this innovative diagnostic approach to everyday clinical work.

Disinfecting ambulances with UVC light

Disinfection with short-wave ultraviolet light (UVC) has been a standard technique for decades, e.g. in drinking water treatment. However, the relatively new UVC LED technology is opening up new applications. It was used for the first time in Ilmenau, where it proved to be a reliable means of disinfecting ambulance interiors in less than 15 minutes – and not just the surfaces, but also the air.

To make this possible, a UVC LED irradiation module is integrated directly into the modular lighting system in the ceiling of the vehicle. Compared to conventional and inexpensive mercury vapor lamps, UVC LED spotlights are durable and vibration-resistant, and are therefore extremely well-suited for mobile use while on the road. They have no warm-up times and offer more efficient emission wavelengths for inactivation of bacteria, viruses and fungi. The radiation characteristics can be adjusted very precisely using attachment lenses and the minimum radiation doses required for reliable disinfection can also be efficiently monitored by electronic means. In the context of the coronavirus pandemic, it is particularly useful that not just the surfaces but also the air inside the ambulance is disinfected.

The technology, system development and design, and field testing are based on a cooperation program between the Fraunhofer Institute for Optics, System Technologies and Image Exploitation IOSB and BINZ Ambulance- und Umwelttechnik GmbH in Ilmenau. The system is the result of three



A new study is researching the mechanisms of metastasis.

years of development time and a complex optical design supported by simulations. New advances in UVC LED technology were also integrated. The model tests were very promising, with the surfaces inside the ambulance being cleaned of up to 99.999 percent of viruses and bacteria – in just ten minutes.

Entire rooms can be disinfected quickly with UVC light. The surfaces inside the ambulance are cleaned of up to 99.999 percent of viruses and bacteria – in just ten minutes.



Artificial Intelligence

Identifying fake news

Providing guidance in times of fake news and conspiracy theories has become a major challenge for the media. The international media monitoring company pressrelations is collaborating with the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE as well as NewsGuard, a company that evaluates the credibility and transparency of news websites, to develop a smart system for identifying potential fake news and disinformation campaigns. To achieve this, the three partners are combining the artificial intelligence with journalistic expertise in a complementary process.

The tool developed by Fraunhofer FKIE allows the automated evaluation of news items and their associated metadata and shows indicators of deliberately disseminated disinformation. Based on manually classified sample posts, machine learning techniques were used to train an engine in order to be able to analyze vast quantities of data automatically. For this purpose, the media monitoring company pressrelations is providing the two million news items that are processed there every day. Not just the posts themselves, but also source sites that distribute them can show signs of fake news. The company NewsGuard uses trained journalists to assess the credibility of thousands of media sites in Europe and the U.S. based on various criteria. At NewsGuard, the researchers are hoping to learn more about the connections and differences between editorial practices and how this is reflected in articles.

The new disinformation detection system is designed to provide media users with guidance on fake news without censoring the content in question. One of the first use cases for the newly developed tool was the cross-media analysis of the U.S. election

campaign that started in July 2020 during the coronavirus pandemic. The new indications of disinformation were taken into consideration for the first time at pressrelations for analyzing the reporting in DACH and U.S. media. The tool developed by Fraunhofer FKIE creates topic-based clusters, for example, which it can then use to identify differences in word choice between trustworthy and untrustworthy media; this information is in turn incorporated into the analysis.

Safe AI: Making self-driving vehicles safer

Technologically, self-driving vehicles are within reach. However, before implementation, it must be proven that they are safe for all road users. To be able to react adequately, an self-driving vehicle must be able to reliably perceive its surroundings and recognize other road users, such as pedestrians.

Artificial intelligence based on machine learning is increasingly used to monitor the surroundings in highly automated vehicles. One of the greatest challenges here is to guarantee the same customary level of functional safety as previous systems because established safety processes are not automatically transferred to machine learning processes. Consequently, in the research project "Safe AI", a consortium of companies and institutions is working on achieving the greatest possible safety in AI functions and standardized interfaces. Experts from the specialist areas of AI algorithms, 3D visualization and animation as well as functional safety are cooperating in the project. Among other things, the 25 partners are pursuing the goal of developing a stringent and verifiable line of reasoning for ensuring the safety of and approving AI function modules. The knowledge gained in this process should form the basis for an industrial consensus



A tool for automated news evaluation was used for the first time in a cross-media analysis of the U.S. election campaign, beginning in July 2020.



– developed in dialog with standardization bodies and certification authorities – on ensuring the safety of AI function modules, thus strengthening the position of the German automotive industry for the long term.

In addition to the consortium leader Volkswagen AG, the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS has taken on deputy leadership and scientific coordination of this research project as part of the German Association of the Automotive Industry's flagship initiative on autonomous and connected driving. The Fraunhofer Institute for Cognitive Systems IKS is participating in the safety argumentation subproject.

Self-steering cargo ships

Thanks to an autonomous steering sensor and navigation system, cargo ships will be able to pilot themselves between defined departure and arrival points, eliminating the need for round-the-clock manning of the bridge.

In the B ZERO project, the Fraunhofer Center for Maritime Logistics and Services CML is developing an artificial intelligence system with reinforcement learning. In this paradigm, the system is not given any information in advance, but rather must work out suitable decision-making guidelines, solely on the basis of the results of and reactions to its own actions. To prevent potential collisions and grounding, Fraunhofer CML is drawing

The Fraunhofer Center for Maritime Logistics and Services CML is developing an artificial intelligence system with reinforcement learning for automated steering of cargo ships.

on experience gained from object detection and robotics. The AI system is trained using simulations of nautical scenarios. Various parameters are available for this, including the number of approaching ships, maritime areas, visibility and weather conditions. The decision-making component that must be taught – e.g. collision avoidance – recognizes the required status in accordance with specified framework conditions. To guarantee a safe passage, the system reacts using the navigation and course changes it has learned.

Using AI-assisted image analysis (computer vision), in particular, digital images can be recorded and processed as numeric information for further machine-based analysis. The key technology allows the automated monitoring of conditions and the detection of changes. In shipping, this can be used to detect even gradual changes, such as erosion of quay walls or deformed ship hulls – as well as the position of loading units on board or at the terminal and damage detection on containers. A prototype was validated in the

fall 2020 during tests on board a freight ship in the port of Rotterdam.

B ZERO is a project funded by the German Federal Ministry for Economic Affairs and Energy. Partners include the Fraunhofer Center for Maritime Logistics and Services CML, the Fraunhofer Institute for Communication, Information Processing and Ergonomics FKIE, the German Federal Maritime and Hydrographic Agency, and the companies Wärtsilä SAM, Hoppe Bordmesstechnik, NautilusLog and the Bernhard Schulte Group.

Bottom:

Dr. Annelie Schiller brought digital holography of moving objects to a new level.

Right:

Using new mathematical methods, the research team at Fraunhofer ITWM is achieving promising advances in making supply chains more resistant.

Hugo Geiger Prize

Digital holography for moving objects

Dr. Annelie Schiller made significant advances in digital holography through her dissertation at the Fraunhofer Institute for Physical Measurement Techniques IPM. This optical measurement technique is already used in industrial manufacturing to quickly and



accurately check the quality of components. The system delivers ten million fully analyzed 3D points within 100 milliseconds. Laser light is used to illuminate the surface of the object.

Previously, this was only possible for stationary components. However, thanks to the research carried out by Dr. Schiller, it is now possible to measure moving objects as well. Rotating objects present a particular challenge in this context. Here, the researcher discovered that the critical velocity of an object does not depend on its radius, rather on the angular velocity and position of the sensor.

This is a major advance for quality assurance in industry, as it facilitates rapid, uncomplicated quality control even for components that previously presented challenges, e.g. for examining gears for aircraft engines or for gearboxes in electric vehicles. In future, these no longer have to be kept stationary for holographic surveying, but can be accurately measured down to the micrometer level while in motion.



Algorithms for stable supply chains

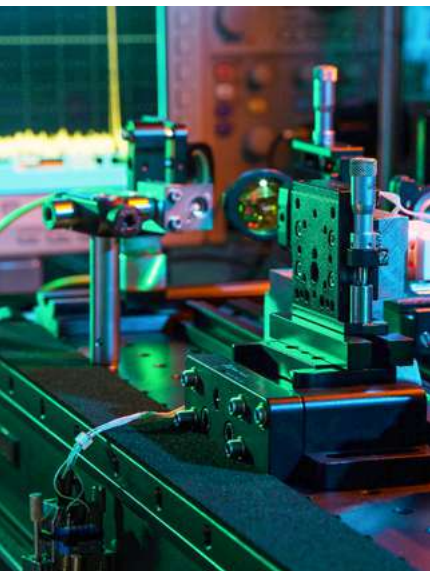
The coronavirus crisis has shown how fragile supply chains can be. From medical breathing masks, infection control products and drugs in the healthcare sector to steering wheels and electronic system components for the automotive industry, shortages were experienced due to restrictions in the global exchange of goods.

New mathematical methods developed by the Fraunhofer Institute for Industrial Mathematics ITWM provide a promising piece of the puzzle for more resilient supply chains. They can be used to calculate the balance between risk and costs. The algorithms analyze how diversified the supply chains are in different divisions of the company and thus how great the risk is of running into drastic supply problems in an emergency. The mathematical method of optimization based on multiple criteria makes it possible to find the individual optimal balance for a company – minimizing supply risks at very little extra cost.

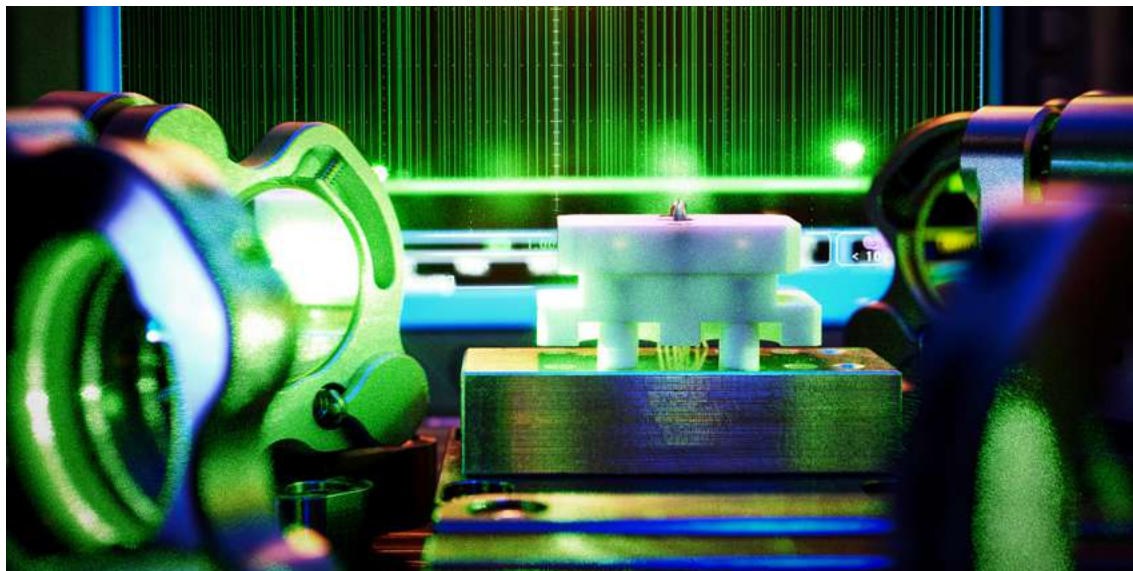
Companies start by entering various parameters on the protected platform developed by Fraunhofer ITWM, e.g. areas in which they think disruption could be likely and how long that disruption might last. The algorithms then calculate various cost/risk figures for this exact raw material, including the possible supplier allocations for this raw material. Using optimizations based on multiple criteria, options such as maintaining a stock of critical products in order to bridge any temporary supply shortfalls or substituting materials, can also be considered.

Procter & Gamble is already using a version of the software that has been significantly expanded and specially tailored to its needs. Other use cases for water supply, transport logistics or distribution networks for replacement parts have been implemented at Fraunhofer ITWM.

Quantum Technologies



QFC-4-1QID – a low-noise frequency converter for the first quantum Internet demonstrator.



Converters for the quantum Internet

The quantum Internet should not only allow secure communication, but also enhance the performance of quantum computers and make them available for users worldwide via confidential access. A concept that is still being researched in laboratories today is set to become reality in 2022 in the form of an initial prototype across four cities in the Netherlands.

In the German/Dutch research project “QFC-4-1QID – Low-Noise Frequency Converters for the First Quantum Internet Demonstrator”, researchers are building a highly efficient low-noise quantum frequency converter (QFC) for the conversion of photonic quantum states. For transmission of the optical quantum information using glass fibers and for low transmission losses, the photons emitted by qubits must be converted so that their wavelengths fall within the range for telecommunications bands between 1500 and 1600 nanometers. So far, only the basic principle of this type of QFC has been demonstrated.

If the pioneers at the Dutch research center QuTech and the Fraunhofer Institute for Laser Technology ILT achieve their goal, they will have found a key component. A major challenge in designing the QFC is achieving high overall efficiency, while simultaneously ensuring low noise in the output signal. The frequency converter will be tested on the quantum Internet demonstrator in the Netherlands in 2022.

QuTech is a joint research center of the Netherlands Organization for Applied Scientific Research (TNO) and the Delft University of Technology. Its mission is to support the Dutch government’s quantum initiative. One of the goals is to develop a quantum Internet demonstrator based on qubits whose entanglement is retained over long distances and long time periods. This involves connecting qubits in Delft, Leiden, The Hague and Amsterdam to a shared quantum system via glass fibers.

Data security for the future quantum Internet

At the beginning of December 2020, the QuNET initiative by the German Federal Ministry of Education and Research presented technologies for a quantum-secured connection between two federal entities.

New types of quantum computers are able to bypass encryption methods that are widely used to secure data exchange. For this reason, the QuNET consortium is researching tap-proof communication and has demonstrated components and systems for the secure exchange of information between two federal entities. To achieve this, the project partners are exploring the overall architecture for systems for quantum-secure communication as well as the possibilities for exchanging quantum keys over long, medium and short distances using free-beam and fiber systems. To this end, new methods are being combined with established processes from classical cryptography and existing telecom technology will also be used to a large extent. For transporting quantum states over long distances and across borders, research is being conducted on optical free-beam systems using aircraft and satellite-compatible technologies.

The Fraunhofer researchers are focusing on free-beam and fiber systems for quantum-based communication over short and medium distances. They are exploring possibilities in relation to integrating quantum technology into fiber optic cables, to quantum light sources and to telescopes, which can be used to create short-term and mobile connections. They are also focusing on the development of interfaces between the various subcomponents and their implementation in existing communication network infrastructures.

The aim of the initiative is to preserve Germany's technological sovereignty as well as data security and confidentiality, even in the face of new technologies. The project partners comprise the Max Planck Institute for the Physics of Light, the DLR Institute of Communications and Navigation and the Fraunhofer Institutes for Applied Optics and Precision Engineering IOF and for Telecommunications, Heinrich-Hertz-Institut, HHI.

Fraunhofer Competence Network Quantum Computing

The nationwide Fraunhofer Competence Network aims to advance the key technology of quantum computing in Germany and develop new technological solutions as well as quantum-based computing strategies for problems in applied, business-relevant areas. At the heart of the competence network is an open research platform based around an IBM Q System One quantum computer. Located in Ehningen in Baden-Württemberg, the computer is for the exclusive use of

the Fraunhofer-Gesellschaft and its partners. The quantum computer is operated under German legislation, which is an important advantage for users in terms of data protection and IP security.

Knowledge platform and app store for quantum-supported artificial intelligence

The objective of the PlanQK project is to open up access to the future generation of quantum computers for science beyond physics and mathematics, and for industry, including SMEs. In collaboration with 18 partners, the Fraunhofer Institute for Open Communication Systems FOKUS is developing an open platform for quantum-supported artificial intelligence – essentially a knowledge platform and an app store for QAI. AI and quantum computing specialists, developers, users, customers, service providers, and consultants can exchange information here, and quantum algorithms in AI applications from machine learning and optimization are developed and made available. Use cases are being developed, showing how the relevant problem could be solved using a classical AI algorithm and which quantum-based alternatives and hybrid combinations are available.

Possible applications include not only detecting fraud in the banking sector but also predicting it, or finding new ways of optimizing timetables. The PlanQK project is a project funded by the German Federal Ministry for Economic Affairs and Energy.

Hugo Geiger Prize

Using ultrashort pulse lasers on glass and ceramics

In his dissertation, Dr. Christian Kalupka from the Fraunhofer Institute for Laser Technology ILT made an important contribution to expanding knowledge of the behavior of laser beams in glass and other transparent materials. Using pump-probe microscopy with a resolution in the femtosecond range, he was able to monitor the temporal and local material excitation caused by the laser pulses and thus analyze the effect of different forms of beam focusing, which are the ultimate cause of modifications to the material.

Through these research results, it is now possible to define the energy deposition and the beam shape of the laser pulse for a desired application for the first time. This can be used for practical, highly efficient laser-based cutting and ablation processes for glass and ceramics in industry, and for novel applications in quantum technology. Transparent materials and semiconductors for systems engineering applications can be manufactured even more precisely using this new method.

Next Generation Computing

Hugo Geiger Prize

A new mix of materials for neuromorphic computing

In his dissertation at the Fraunhofer Institute for Silicon Technology ISIT, Dr. Simon Fichtner researched the new piezoelectric thin-film material, aluminum scandium nitride (AlScN), and discovered that it becomes ferroelectric when it contains more than 27 percent scandium.

Ferroelectric materials act as a basis for intelligent electronic components and thus for next-generation computing. This materials class enables neuromorphic computing, stores information, is used in energy-efficient transistors or acts as an actuator. The newly developed AlScN is far superior to established materials. The German Federal Ministry of Education and Research as well as the American research authority DARPA are funding further research into AlScN.

Three scientists from Fraunhofer IIS have developed server-based satellite navigation technology which is freely available worldwide at all times, highly accurate, safe and trustworthy.

Joseph von Fraunhofer Prize

Trustworthy satellite navigation

Global navigation satellite systems (GNSS) with positioning and timing infrastructure allow a wide variety of applications, e.g. for the police, fire service, customs and humanitarian aid services. Applications in (self-driving) transport, power grids, goods tracking, machine navigation, stock exchange trading, communication infrastructure, and much more are also possible. Up to now, however, such civil applications have depended on military satellite solutions, such as GPS.

Until this point, infrastructure and industry have mostly used unsecured GNSS data, which is vulnerable to manipulation by jammers or spoofers. Based on what were previously the only fully cryptographically protected GNSS signals under civil control – Galileo Public Regulated Service (PRS) –



experts at the Fraunhofer Institute for Integrated Circuits IIS developed a server-based satellite navigation technology that is freely available worldwide at all times, and also highly accurate, secure and trustworthy. In so doing, they have made an important contribution to the technological sovereignty of Germany and Europe.

Over ten years of research has resulted in innovations such as new types of miniaturized array antennae and affordable, low-power receivers. The new server-based PRS process records verified location and time signals in a receiver and analyzes them in a special infrastructure. Fraunhofer IIS in Nuremberg operates the world's first server-based PRS receiver system. Alexander Rügamer, Dr. Günter Rohmer and Dr. Wolfgang Felber from Fraunhofer IIS were awarded a Joseph von Fraunhofer Prize for the development of receiver technologies based on Galileo PRS over a period of ten years.

Cryogenic 3D nanoelectronics for quantum computers

3D nanoelectronics for extremely low-temperature applications are set to help improve key technologies for quantum computers. Nine consortium partners, including the Fraunhofer Institute for Applied Solid State Physics IAF, are researching this issue in the EU project SEQUENCE.

Controlling quantum computers means controlling qubits. As the states of these extremely small units of information are very unstable, the qubits must be cooled to extremely low temperatures below -270°C . This cryogenic operation makes it difficult to connect the qubits to the power management, readout and control electronic systems that are needed for the computing processes. Long connecting cables, which are connected individually to the cooled qubits, are currently used for quantum computers. This poses considerable restrictions for the setup of the systems.

For future quantum computer applications, the qubits must be increased significantly in number and connected with electronics

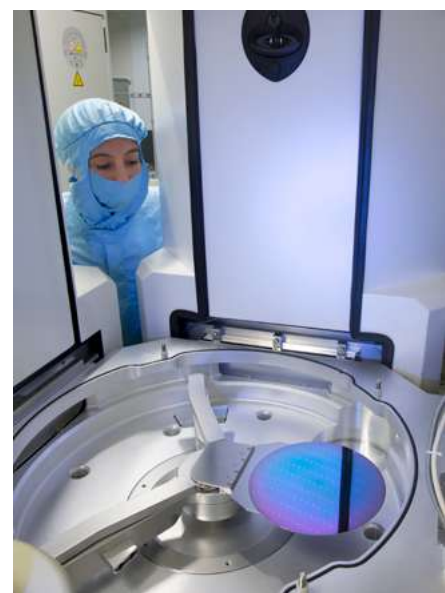
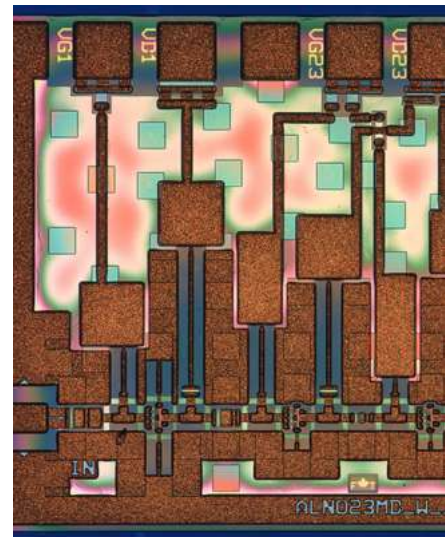
that can be cooled and placed close to the qubits. These electronic components must not disturb the sensitive qubits. They must therefore operate with very little noise, at low temperatures and with negligible self-heating. To develop electronic components that are suitable for these extremely low temperatures, the SEQUENCE project partners are combining Si-CMOS, III-V and 3D integration technologies. They are designing various high-frequency circuits, such as low-noise amplifiers, mixers, oscillators, digital-to-analog converters, multiplexers and high-frequency switches, which operate at extremely low power levels and can even achieve better performance levels at low ambient temperatures. These cryogenic electric components will assist in the scaling of both superconducting and spin-qubit-based quantum computers.

Fraunhofer IAF is supporting the SEQUENCE consortium with its many years of experience in circuit design, low-temperature measurement technology for ultra-low-noise high-frequency electronics, and in particular, cryogenic electronics in radio astronomy.

Decentralized artificial intelligence computing on computer chips

In 2020, three Fraunhofer Research Institutions and European partners started work on developing a neuromorphic computer chip in the EU project ANDANTE. The goal is to bring the most energy-efficient AI chip in the world to market-readiness by 2023. To this end, the researchers are striving to achieve an efficiency of more than 1000 TOPs (tera operations per second) with a power input of just one watt.

The new hardware for electronic systems should make it possible to conduct power-saving calculations directly on the semiconductor chip. This will enable very rapid, decentralized, energy-efficient data processing for artificial intelligence applications. This means that in future, AI calculations will be performed decentrally, directly on sensors and other smart devices – edge AI will become reality.



Top:
A low-noise amplifier,
manufactured using 35 nm
HEMT technology developed
by Fraunhofer IAF.

Bottom:
Thermally assisted chemical
vapor deposition on an 8-inch
wafer.

The novel hardware for electronic systems is set to allow power-saving calculations directly on the semiconductor chip.

The consortium partners are exploring possibilities for using new types of storage components in extremely small technology nodes to expand the applications of edge AI. The improvements include an efficient circuit design, optimal architectures and the use of new non-volatile storage technologies. The energy-efficient, upscaled chips required for this will be manufactured using the 22FDX technology developed by Globalfoundries. Initial areas of application relate to self-driving vehicles, industrial automation and health. In this way, the project is making an important contribution to safeguarding Germany's competitiveness and expanding Europe's technological sovereignty.

ANDANTE is a funding line of the public-private partnership ECSEL, which is part of the EU Framework Program Horizon 2020. Project participants include the Fraunhofer Institutes for Integrated Circuits IIS and for Photonic Microsystems IPMS as well as the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT.

Key elements for the digitalization of medium-sized companies

To ensure that smaller-scale system suppliers – as drivers of innovation – are also able to shoulder the growing level of effort involved in developing and manufacturing next-generation electronics, a Fraunhofer consortium from Saxony is working together with Globalfoundries to develop a "Universal Sensors Platform" (USEP).

A wide variety of innovative solutions for hardware and IT security have been integrated into the platform. It combines state-of-the-art development and packaging technologies with the latest semiconductor design methods and allows the integration of a broad range of different sensors. The foundation of the Universal Sensors Platform is the 22FDX technology developed by Globalfoundries in Dresden, which allows the use of affordable, power-saving chips based on the "Fully depleted silicon on insulator" principle (FDSOI). The consortium combined expertise from the areas of innovative chip design, concept

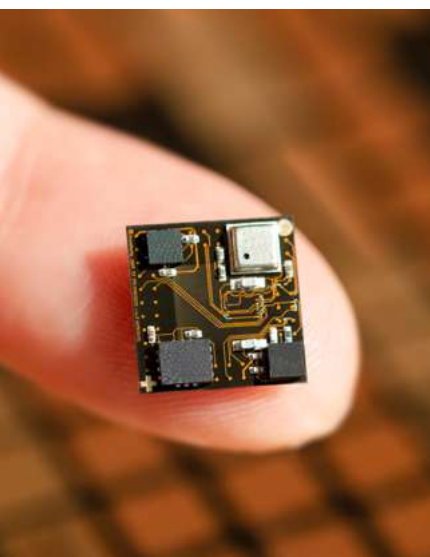
development, system design, security, sensors, data transmission and simulation and testing. To ensure that companies can continue to use the universal sensor platform for as long as possible, the research partners made sure that the results could be transferred to the next generations of the semiconductor technology used. The start-up Sensry will transform the platform and its further development in cooperation with the technology partners into products and thus provide the users with flexible and customer-specific sensor and communication solutions.

USEP is a project run by the Fraunhofer Institute for Photonic Microsystems IPMS, the Fraunhofer Institute for Electronic Nano Systems ENAS, the branch All Silicon System Integration ASSID of the Fraunhofer Institute for Reliability and Microintegration IZM and the branch Engineering of Adaptive Systems EAS of the Fraunhofer Institute for Integrated Circuits IIS, with support from colleagues from Berlin and Erlangen as well as the Fraunhofer Institute for Applied and Integrated Security AISEC. It was funded by the EU as part of the European Regional Development Funds (ERDF) and by the state of Saxony.

Power-saving chips for neuromorphic computing

Previous types of chips needed large quantities of energy for complex computing. Neuromorphic computing, which takes the efficient nerve network in the human brain as an abstract model, is considered a key technology for next-generation computer applications. As part of the EU Framework Program Horizon 2020, the public-private consortium ECSEL has set itself the task of developing power-saving neuromorphic chips.

The German consortium is researching chips using the 28-nanometer technology node and 22FDX technology from Globalfoundries. In these small technology nodes, connection establishment can be made smaller, and leakage currents and process fluctuations can be reduced, both for analog and digital neuromorphic circuits. The chips developed in this way are to be used initially for classification tasks for image recognition systems,



A Fraunhofer consortium from Saxony, in cooperation with Globalfoundries, has developed a "Universal Sensors Platform" (USEP) for smaller-scale system suppliers.

e.g. for self-driving vehicles or for processing sensor data in radar systems.

New technologies for in-memory computing and demonstrators are used to make neuromorphic circuits a reality. The goal is to use such embedded memory cells and adapted peripheral devices to reduce power consumption by several orders of magnitude.

The TEMPO project is funded by the EU as part of the ECSEL initiative and by the German Federal Ministry of Education and Research. The Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT and the Fraunhofer Institutes for Integrated Circuits IIS and for Photonic Microsystems IPMS are participating in the project.

New technologies for in-memory computing and demonstrators are used to make neuromorphic circuits a reality.



Verification of the deep learning algorithm for the implementation of neuromorphic hardware.

Awards in 2020



German President Frank-Walter Steinmeier (from left) with the German Future Prize winners: Dr. rer. nat. Michael Kösters, Dr. rer. nat. Peter Kürz, Dr. rer. nat. Sergiy Yulin (Fraunhofer IOF).

German Future Prize

New light for the digital age

The German Future Prize 2020 went to a team of researchers from ZEISS, TRUMPF and Fraunhofer for the development of EUV lithography. As the leading manufacturing technology in the world, e.g. for the latest smartphones or automated driving, this lithography process using extreme ultraviolet (EUV) light strengthens the German-European position in the global semiconductor industry. For their work in this area, Dr. rer. nat. Michael Kösters (TRUMPF), Dr. rer. nat. Peter Kürz (ZEISS) and Dr. rer. nat. Sergiy Yulin (Fraunhofer Institute for Applied Optics and Precision Engineering IOF) were awarded the German Future Prize, the Federal President's Award for Technology and Innovation, by Frank-Walter Steinmeier.

With their project "EUV lithography – New Light for the Digital Age," the winning team made a significant contribution to developing the EUV technology and preparing it for industrial mass production. This future-oriented technology, backed by over 2000 patents, forms the basis for the digitalization of our everyday lives and will pave the way for applications such as self-driving vehicles, 5G, artificial intelligence, and other future innovations. At present, EUV technology has led to the creation of over 3300 high-tech jobs

at ZEISS and TRUMPF and an annual turnover of more than one billion euros in 2019 – an upward trend that is still continuing.

The Dutch company ASML, which designed the EUV source in particular, as well as the overall system architecture, is the only manufacturer of EUV lithography machines in the world. Key components of these machines are the high-performance laser from TRUMPF for the EUV light source, and the optical system from ZEISS. Fraunhofer was an important research partner in developing the sophisticated coating technology for the large mirrors. From the light source and the optical system in the vacuum right down to the surface coating of the mirrors used, practically the entire lighting technology had to be redeveloped from scratch so that significantly higher-performance, more energy-efficient and cost-effective microchips than ever before can be manufactured today.

Awarded annually since 1997, the German Future Prize is one of the most prestigious accolades for scientific achievement in Germany and is worth €250,000. For Fraunhofer, this is the ninth time it has received the German Future Prize, and the third time for Fraunhofer IOF.

*Project manager
Prof. Dr. Nils Urbach.*



Living labs innovation award from the German Federal Ministry for Economic Affairs and Energy

Digital validity register for legal documents

Digital solutions are also needed for applications where a particular degree of legal certainty is required, such as power of attorney documents and certificates of inheritance. The German Federal Chamber of Notaries, the Bavarian State Ministry of Justice and the blockchain laboratory at the Fraunhofer Institute for Applied Information Technology FIT have collaborated to develop a prototype for a digital validity register.

Based on blockchain technology and always tamper-proof, the register indicates whether a power of attorney document or a certificate of inheritance is still valid. This protects data and makes it easier for citizens, notaries and courts to use the documents. It could also replace paper documents and lengthy court proceedings required for declarations of invalidity. Alongside the development of this innovative prototype, the results were also recorded in a whitepaper, in which the project team addressed specific questions, such as IT security or rights and role management.

The blockchain-based validity register was selected from among 135 contributions as the winner in the retrospectives category of the living labs innovation award from the German Federal Ministry for Economic Affairs and Energy. The project also won an award in the eGovernment competition sponsored by the German Head of the Federal Chancellery, Helge Braun, receiving third prize in the best cooperation project category. The first two prizes in this category also went to projects in which Fraunhofer FIT is playing a key role. Joint first prize went to a project on digital certificate networks with the North Rhine-Westphalia Ministry of Economic Affairs, Innovation, Digitalization and Energy, and a project on a digital strategy for Hamburg in cooperation with the senate chancellery of Hamburg.



*Dr. Sabine
Amberg-Schwab.*

Sustainability Award

Material for sustainable packaging

Since 1989, Dr. Sabine Amberg-Schwab of the Fraunhofer Institute for Silicate Research ISC has been researching coating materials. In 2020, the chemist won numerous awards, including the German Packaging Gold Award 2020, and two categories of the Sustainability Awards 2020, a pan-European prize.

Dr. Amberg-Schwab won the Sustainability Award 2020 from Packaging Europe for the development of bioORMOCER®s and a sustainable material concept for environmentally friendly plastic packaging. The jury of the leading information medium for Europe's packaging industry praised the fact that the ORMOCER® material class not only enhances the properties of bioplastics and paper, but can also be used to make plastic packaging generally recyclable. This is because the barrier layers made from ORMOCER®s allow pure-grade plastics to be used for packaging, which in turn can be used to produce recyclable monomaterial packaging. The bioORMOCER® material class goes one step further: the bioorganic compounds are manufactured using by-products from food production and from biological waste streams. Since the functional barrier layers are compostable, this means that compostable packaging is now also within reach.

Dr. Amberg-Schwab and her research team did not just win in the "Bio-Based Packaging" category: Their packaging concept for recyclable or compostable plastic packaging was so convincing that the team emerged as overall winner in all eight categories of the annual pan-European competition. The scientist has previously won the German Packaging Gold Award.

The f-cell Award was presented to Dr. Roman Keding (center) and Dr. Matthias Klingele by the Baden-Württemberg Minister of the Environment, Franz Untersteller (left).



f-cell Award

Fuel cells with more power

Scientists at the Fraunhofer Institute for Solar Energy Systems ISE succeeded in increasing the power of fuel cells by approximately 10 percent compared with fuel cells that are normally used in the automotive sector. The researchers also managed to optimize the cost efficiency, speed and reliability of the production process without having to use more or better materials.

When it comes to industrial manufacturing of solar cells, the researchers at Fraunhofer ISE have decades of experience in using flatbed screen printing for the production of homogeneous layers as stacks. The technology has now been advanced as a scalable manufacturing process for the production of fuel cell electrodes with high throughput and high quality. To achieve this, the departments "Production Technology – Structuring and Metallization" and "Fuel Cell Systems" have worked together and combined their expertise in photovoltaics and hydrogen technology. The continuous ionomer-graduated catalyst layers developed in this way enable a significantly improved power density during the operation of fuel cells.

The DEKADE project, funded by the German Federal Ministry of Education and Research, won the f-cell Award in the "Research & Development" category. First presented in 2001, the award acknowledges outstanding developments in the future-oriented fields of technology, hydrogen and fuel cells. The award is supported by the Ministry of the Environment, Climate Protection and the Energy Sector Baden-Württemberg and Wirtschaftsförderung Region Stuttgart GmbH.



At the awards ceremony (from left): Prof. Dr. Alexander Martin, director of Fraunhofer IIS; Norbert Schäfer, CEO of CNA e. V.; Dr. Andreas Bärmann, Universität Erlangen-Nürnberg and Fraunhofer IIS; Dr. Stefan Wimbauer, Bavarian Ministry of Economic Affairs, Regional Development and Energy; Frederik Nöth, VAG Verkehrs-Aktiengesellschaft Nürnberg.

Intelligence for Transportation and Logistics innovation prize

Mathematics allows more energy-efficient timetables in Nuremberg

“Energy-Efficient Timetable Optimization in the Nuremberg Underground System” won the Intelligence for Transportation and Logistics innovation prize. The award is given every year by the Center for Transportation & Logistics Neuer Adler (CNA)/Railway Technology cluster.

Thanks to innovative algorithms, departure times and driving speeds can be fine-tuned to such an extent that energy peaks can be reduced and optimal use can be made of recuperated energy from braking trains. The optimizations not only increase passenger satisfaction, but also minimize costs and help the climate. The project was conducted by the Fraunhofer Institute for Integrated Circuits IIS and by VAG Verkehrs-Aktiengesellschaft Nürnberg. It is based on previous research work conducted by the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) as well as the ADA Lovelace Center’s further development of mathematical problems in the area of graph theory. As a cooperation platform for science and industry, the ADA Lovelace Center for Analytics, Data and Applications combines AI research with AI applications in an innovative way.

The Intelligence for Transportation and Logistics innovation prize is presented to companies for outstanding projects, products or services that make a significant contribution to long-term economic growth, job safeguarding and continued competitiveness in Bavarian industry.



Ideas Competition for International Research Marketing of the DFG

Microelectronics trends blog

The Deutsche Forschungsgemeinschaft (DFG) (German Research Foundation) has awarded the Fraunhofer Institute for Reliability and Microintegration IZM a prize in the Ideas Competition for International Research Marketing. The prize was awarded for the concept of a scientific blog "ReallZM" in the field of microelectronics.

The platform is intended to facilitate a global exchange of knowledge and increase the importance of research priorities and research institutions on an international level. Nationally and internationally qualified researchers and interested parties will also be included and promoted. The blog will also include general reporting on the latest trends and technologies from industry and science. The uniqueness of the idea lies in the combination of information, communication and openness. It is not only about access to scientific, application-oriented topics and futuristic trends, but also about digital cooperation between renowned researchers and visionaries from all over the world. The conception and development of the blog was financed through special funds from the German Federal Ministry of Education and Research.



Innovation Award North Rhine-Westphalia – Honorary award

Blazing a trail for Industrie 4.0 in logistics

Prof. Dr. Michael ten Hompel received a prize in the honorary category of the North Rhine-Westphalia innovation awards. The executive director of the Fraunhofer Institute for Material Flow and Logistics IML and chair of Materials Handling and Warehousing at TU Dortmund University received this award as an innovator for the Internet of Things and a pioneer of Industrie 4.0 in logistics, as well as for his role in founding the European Blockchain Institute.

As he was awarded the honorary prize, Prof. ten Hompel presented the first pioneering prototype from the Blockchain Institute – the blockchain device: It can reliably monitor and control temperature-sensitive goods, such as food, medicines or vaccines along global supply chains. In the future, such devices will actively negotiate via smart contracts, trigger transactions and book payments. This means that every action can be clearly identified and tracked via the blockchain network.

During the awards ceremony, Prof. ten Hompel pointed out that the Internet of Things is now becoming the Internet of values. In the near future, not only in logistics, it will be a matter of "no blockchain – no deal".



Center:

*Prof. Dr. Michael ten Hompel
with the innovation award
from North Rhine-Westphalia.*

Right:

*Prof. Dr. Melanie
Jaeger-Erben.*

Transformative Science research prize

Sustainability research in electronics

Prof. Dr. Melanie Jaeger-Erben received the “Transformative Science” research prize worth €25,000 from the Wuppertal Institute and the Zempelin-Stiftung within the Stifterverband für die Deutsche Wissenschaft e. V. The award, which has been bestowed for the third time, honors scientific achievements that trigger a social impact using interdisciplinary and trans-disciplinary methods.

The focal points of Prof. Jaeger-Erben’s work are consumption and social science-related technology research, as well as social innovation and social change. The psychologist and sociologist specializes in strategies for promoting sustainable production and consumption systems. Jaeger-Erben is head of the “Obsolescence as a Challenge for Sustainability” junior research group. The joint team from the Technical University (TU) of Berlin and the Fraunhofer Institute for Reliability and Microintegration IZM develops strategies for sustainable production and consumption practices in electronics. The phenomenon of obsolescence, that is, electronic devices with excessively short service lives, has social, economic, engineering and legal implications.

People in research



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

- 1 Dr.-Ing. Anna Hilsmann
- 2 Dr. rer. nat. Sergiy Yulin
- 3 Prof. Dr. Julia C. Arlinghaus
- 4 Prof. Dr. Christian Brecher
- 5 Maria Kuzikov
- 6 Prof. Dr. rer. pol. Jakob Edler

Dr.-Ing. Anna Hilsmann

Engineer | Head of the “Computer Vision & Graphics” group at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI in Berlin

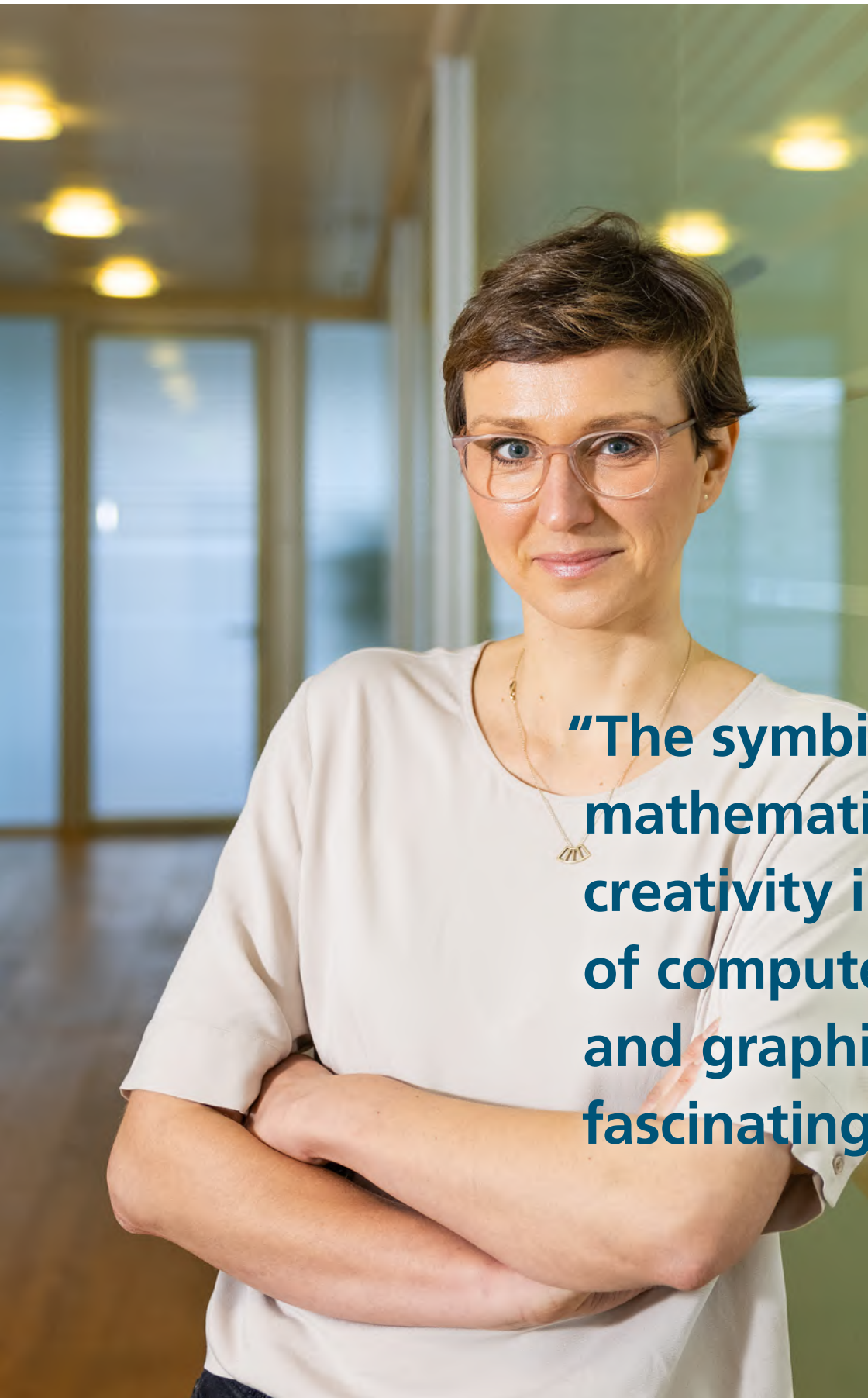
“I really enjoy the work here,” emphasizes Anna Hilsmann, head of the “Computer Vision & Graphics” group at Fraunhofer HHI. She researches innovative ideas in the field of image, video and scene analysis and combines methods of machine learning, computer vision, computer graphics and visual computing to develop new solutions for applications in multimedia, industry and augmented reality as well as for security and medical engineering. New initiatives were added to this in 2020: Anna Hilsmann won a funding project worth over €1.6 million organized by the German Federal Ministry of Education and Research in the area of artificial intelligence. With this funding, she and her group will research new model-based deep learning approaches in the area of computer vision. Classic model-based methods will be combined with neural learning so that the algorithms will take physical restrictions and causal links into consideration.

The researcher reports that attracting mainly female junior scientists for this AI project is proving to be a challenge. At the same time, she says that it is a matter that is close to her heart. Hilsmann herself was honored with the “ARD/ZDF Förderpreis Frauen + Medientechnologie” advancement award for women in 2016 and she was among the candidates for the “Digital Female Leader Award” in 2020. Her outstanding work is the reason that such honors have been bestowed upon her as a researcher: she has received several Best Paper Awards, and she received the science award from the Association of Berlin Merchants and Industrialists (VBKI) for her dissertation in 2015.

“Research feels more meaningful when it’s for applications in medicine,” says Anna Hilsmann. When she was a child, a friend of hers received a femoral prosthesis following a tumor operation. At that time, she wanted to develop innovative prostheses that could be controlled using nerve endings. Later, Anna Hilsmann decided to study electrical engineering and information technology at RWTH Aachen University, as the course there offered a focus on medical engineering. After that, she wrote her thesis at Philips Research on computer tomography recordings of the lungs and the tracking of tumors during respiratory movements. This led to her interest in research in the area of computer vision and machine vision. That is how she came to Fraunhofer HHI, where she can conduct research and develop innovative applications at the same time – including in medical engineering.

The group’s projects are very diverse. Her team also works on modeling and the realistic animation of people. “The field of computer graphics is already very good at generating photo-realistic humans but, to date, user perception has not been taken into account in human-computer interactions.” In order to change this, Anna Hilsmann wants to collaborate with a team of neuroscientists from the Max Planck Institute for Human Cognitive and Brain Sciences to start a research project on avatar-based translation of sign language.

She is enthusiastic about the possibilities of her work: “I’m fascinated by the area of computer vision and graphics because I consider it to have the ideal combination of IT, mathematics, but also art and psychology. There is always something magical about the creativity in this area.”



“The symbiosis of mathematics and creativity in the area of computer vision and graphics is fascinating to me.”



“Many small innovative steps were important on the path to series production.”

Dr. rer. nat. Sergiy Yulin

Engineer | Senior principle scientist at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF in Jena

Dr. Sergiy Yulin from Fraunhofer IOF was responsible for one of the highlights of 2020. Together with his colleagues from ZEISS and TRUMPF, he received the renowned German Future Prize for a revolutionary method of chip production (see p. 109). The fact that EUV lithography is ready to go into series production today is thanks to almost 30 years of research. And Dr. Sergiy Yulin is a pioneer who was involved right from the start. Throughout his life as a researcher, he devoted his time to investigating the coating of high-performance optic for the extreme spectral range of light. Besides a high-performance laser source (TRUMPF) and precise projection optics (ZEISS), the highly reflective mirror coating is a critical success factor for the technology. To address this, Yulin and his team use a coating system that he developed to affix more than 100 nano-layers of molybdenum and silicon (that must have exactly the same thickness) to the ZEISS mirror – an immense technological challenge.

The engineer's path to success began back in 1983. While studying in his home country of Ukraine, and also during his subsequent doctorate at the Karazin University in Kharkiv, the scientist focused on the perfect coating composition for mirror optics. This was all theoretical, as at that time there were no systems capable of achieving the necessary level of precision for the reflective layers. He therefore started to build one in the 1990s. The story of his success made its way throughout the scientific community and an appointment to Fraunhofer IOF in Jena followed. His "Nessy" device is now in its third generation and is still used by the institute and by project partners to this day. An extraordinary milestone was reached in 2009 when, using Nessy 2, the first EUV collector mirror with a diameter of 66 centimeters and extremely precise layer thicknesses was manufactured. A few years later, however,

the EUV experiment seemed to be headed for failure, primarily because the EUV light sources available were not powerful enough to generate light with a wavelength of 13.5 nanometers. Businesses lost interest, and Yulin's research was running on fumes.

Today, the renowned expert, who is held in high esteem in specialist circles, says that in the final analysis, 30 years of research with setbacks and successes is not all that unusual for a technology of this complexity and for a researcher in his field. There were ultimately several smaller innovative milestones along the way that were important for series production. What has always fascinated him about the work with EUV light is its huge application potential. It can be used for more than just lithographic chip manufacture – it can also open up new insights into yet-unknown spheres in the world of microscopy in the so-called water window, in the observation of outer space or in spectroscopy in the EUV spectral range. Yulin wants to continue to harness this potential. The passionate beach volleyball player is developing increasingly more powerful optics each year, which can be found in renowned research institutions all over the world.

Prof. Dr. Julia C. Arlinghaus

Industrial engineer | Director of the Fraunhofer Institute for Factory Operation and Automation IFF in Magdeburg | Chair for Production Systems and Automation at the Otto von Guericke University Magdeburg

As a child, Julia Arlinghaus dreamed of flying and wanted to be a pilot. When many airlines shut down their training programs after September 11, 2001, she had to come up with a new plan. She found her new goal in a combination of mechanical engineering and business administration and went on to study industrial engineering. Today, the researcher is happy about the breadth of business and technical understanding that her course gave her, and believes that it was an important prerequisite for her current work.

In her capacity as institute director since 2019, Julia Arlinghaus has been responsible for 200 employees as well as the strategic direction and economic success of the Fraunhofer Institute for Factory Operation and Automation IFF. Her mission is to strengthen value creation in Germany and in Saxony-Anhalt. In addition, she also lectures at the Otto von Guericke University Magdeburg as Professor of Production Systems and Automation – following on from her time as W3 Professor of the Management of Industry 4.0 at RWTH Aachen University. It is a perfect combination for her: “This means I can implement findings from the university directly into projects at the institute.”

The native of Bremen wrote her thesis on the organization of factories based on the model of swarming bees at Tokyo University, Japan, in 2007. She did her doctorate in supply chain management in St. Gallen. After working as a consultant at Porsche, she chose to pursue a scientific career. While lecturing as Professor of Network Optimization in Production and Logistics at Jacobs University Bremen, she met many students from developing countries. They were passionately interested in new production techniques and logistics processes – primarily to

modernize the poorly developed infrastructures in their native countries, such as water supply and electricity networks. Since then, Julia Arlinghaus has not let go of the topic of “frugal engineering,” which is the transfer of technological knowledge to structures in developing countries. Today, the researcher is a member of the sustainability advisory board at the Fraunhofer-Gesellschaft, where she wants to raise awareness of this field of application.

What the institute director appreciates most about her work at Fraunhofer is not only the proximity to industry, but also the diversity of topics in particular. From robots for aircraft production to systems for the provision of mobile intensive care – she says that she is sometimes even surprised herself by the multifaceted potential of her institute. The 37-year old works tirelessly on the growth trajectory of Fraunhofer IFF. She recently launched the new business model innovation division, which intends to help local companies develop and introduce new business models. In addition, she would like to reinforce the topic of energy-efficient production and set up a demonstration center for the public by constructing a new technical center named the “Elbfabrik” research factory for trying out and experiencing research.

Despite having big plans for her institute, Julia Arlinghaus, who is the mother of a young son, manages to balance family and career. In the little leisure time that she has, sport is her main hobby. Horse riding in particular brings her somewhat closer to her childhood dream: “When I’m galloping across the field on my horse, it’s almost like flying.”



“I can implement findings from the university directly into projects at the institute.”



**“In production, we show
what is feasible and how
it works.”**

Prof. Dr. Christian Brecher

Mechanical engineer | Director of the Fraunhofer Institute for Production Technology IPT in Aachen | Chair of Machine Tools at the Laboratory of Machine Tools and Production Engineering at RWTH Aachen University

"A mechanical engineer must be able to tackle anything." From an early age, Christian Brecher showed signs of this characteristic that would shape his future career. As a youngster, he burned the midnight oil working on technical issues. And to this day, the engineer is still enthusiastic about practical work in his personal life. "I would love to do even more if I had the time," says the director of Fraunhofer IPT.

Creating something, actually building machines – this is something he also places a particular emphasis on at the institute. "That is the most important thing to master," he emphasizes. For this to be possible, experts from all of the necessary disciplines at Fraunhofer IPT work together. Just recently, the institute received a contract to develop and build a machine to manufacture particularly precise structures. For Christian Brecher, this was a reason to get involved in the design process himself and to study the plans together with the team. "When a prototype like that then works, that's an especially nice moment," he says with delight.

Christian Brecher studied mechanical engineering at RWTH Aachen University, worked as a research fellow and Chief Engineer in the Machine Technology department of the Laboratory for Machine Tools and Product Engineering (WZL) at RWTH Aachen from 1995 to 2001, and completed his doctorate in the faculty of mechanical engineering. He came to Fraunhofer in 2004. At that time, he led the entire design and development division at a machine tools company.

"I was happy in industry," says the scientist. However, when he received the offer to succeed Prof. Dr. Manfred Weck and to become a member of the directorate at the WZL and at Fraunhofer IPT, he jumped at the chance. "I knew that

opportunities like this only come along once in lifetime," he remembers. At the institute, he headed up the production machines department. He was deputy director from 2015 to 2017 and has been director of Fraunhofer IPT since January 2018.

One topic that Christian Brecher is especially concerned with as a scientist is the role of the Internet in production – the digitalization and interconnectedness of all production processes. The aim here is to use all of the data from the manufacturing process to generate knowledge and new business models and ultimately create added value, says the researcher in outlining the task at hand. His sector could also provide vital impetus for key issues in the future: How can we achieve the required sustainability in a responsible and economic way? "In production, we show what is feasible and how it works," says Christian Brecher. For him, the focus is on mobility and energy storage. One of the tasks is therefore to develop production techniques for the cost-effective manufacture of lithium-ion batteries as well as of fuel cell systems at high quality and high quantities.

The Fraunhofer researcher's favorite way to spend his scarce free time is with his family of four. For example, he enjoys playing tennis, climbing high ropes courses with his son and taking hiking trips and cycling tours with his entire family in the tripoint area between the Netherlands, Belgium and Germany.

Maria Kuzikov

Molecular Life Sciences M.Sc. | Employee at the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP, ScreeningPort institute branch, in Hamburg

At the end of November 2020, Europe was in the grip of the second wave of COVID-19. At this time, an article was also published in the ACS Pharmacology & Translational Science specialist journal – with Maria Kuzikov as lead author. The study, entitled “Identification of inhibitors of SARS-CoV-2 3CL-Pro enzymatic activity using a small molecule repurposing screen”, is of special importance to the molecular biologist – both personally and because the publication is part of an EU-wide funding project to combat the coronavirus pandemic.

Eighteen research and industry partners from Europe are working on the “Exscalate4CoV (E4C)” project to find active ingredients in existing drugs that can be used to better treat COVID-19 patients. The consortium includes the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP, which became independent in 2021. Maria Kuzikov works at the institute’s ScreeningPort location in Hamburg. There, they have exactly the type of infrastructure that is sought after in a pandemic: a library of 250,000 molecules, including the Fraunhofer ITMP Repurposing Collection of 5600 substances, automated robotic screening platforms and a high-resolution automatic cell imaging system for high-content screening.

A central task of the project team with Maria Kuzikov is to find substances that inhibit the functioning of proteins in the SARS-CoV-2. Once the virus has entered the cell, it causes it to read its viral RNA and to reproduce the SARS-CoV-2 proteins, and thus start the production of new virus particles. The inhibitors found in the study give reason for hope.

Maria Kuzikov says that, for her personally, such studies show that applied research works. “I’m delighted that as a molecular

biologist in clinical research I can also work with a clear focus on products.” This means she is getting ever closer to fulfilling her professional aspiration: she wants her work in research to be application-based and clinically oriented, and that has been her wish right since she started her studies.

At the age of twelve, Maria Kuzikov moved from St. Petersburg to Greifswald with her parents. She found school life in Germany to be quite simple: little homework, easy material, only five schooldays and a great deal of freedom, such as with regard to students’ behavior. By choosing an interdisciplinary course of study, molecular life science, the researcher was able to combine aspects of the professions of both her parents – a medical specialist and an engineer. At Lübeck, we studied physiology with medical students, subjects such as physics with medical engineering students and IT with aspiring computational life scientists,” she remembers. She chose her internships in such a way that she would gain insights not only from industrial companies, but also from the academic sphere. Following her internship and subsequent master’s thesis, she remained at ScreeningPort in Hamburg.

Her greatest ambition is to be involved in the development of a drug that benefits patients. “Even if the statistics tell us that only one in a hundred of the drugs researched actually make it to the market!”

“I’m delighted that as a molecular biologist in clinical research I can also work with a clear focus on products.”





**"I have always
found the interaction
between academic
ambitions and
contract research
to be productive."**

Prof. Dr. rer. pol. Jakob Edler

Qualified business administrator | Doctor of political science | Executive director of the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe | Professor of innovation policy and strategy at the Manchester Institute of Innovation Research

"At 18, you don't need to know exactly what you want to do as long as you are curious and open," says Professor Jakob Edler, who himself did not plan his career at all. "I chose between my opportunities by following my interests, and today I am where I feel most comfortable: at the intersection between innovation research and providing policy advice," says the native of the Kurpfalz region of Germany, who has been executive director of the Fraunhofer Institute for Systems and Innovation Research ISI in Karlsruhe since October 2018.

Almost 20 years previously, in May 1999, he initially started there as a research fellow in the area of research and innovation policy – directly after completing his doctorate in political science, for which he graduated *summa cum laude*. "At that time, I made the quite deliberate decision to come to Fraunhofer ISI instead of accepting a *de facto* six-year post-doc position, funded by the DFG, at the university. I have always found the interaction between academic ambitions and contract research to be productive," explains Professor Edler, who initially became deputy head of the Innovation Systems and Policy department at Fraunhofer ISI in 2004, and then took over as head of the department two years later.

In 2007, Professor Edler answered the call to work at Manchester Institute of Innovation Research (MIOIR), of which he was head from 2011 until 2018. For twelve years he lived in England, which grew so close to his heart during that period that he now holds British citizenship alongside his German citizenship. The German-Brit visits England regularly, and not just on account of his two children. "The connections between Germany and England in innovation policy are very exciting.

Both countries can learn a lot from one another," says Professor Edler, who gained interesting insights into the parliament when he was a policy advisor in London.

In his current role, Professor Edler advises numerous governments and bodies as well as decision-makers in business and society. He sees the Fraunhofer-Gesellschaft with its interdisciplinary expertise as "a very important player in the necessary transformation in these times when everything is becoming increasingly complex. I find it very exciting to be part of it. With my interests and qualifications and the excellent and highly-motivated employees at Fraunhofer ISI, I have the most wonderful job that I can imagine."

His institute is particularly concerned with the question of how sustainable transformation can succeed in all spheres of life and in all functional areas. "Unlike traditional innovation research institutes, we at Fraunhofer ISI always have an eye on the interaction between innovation and system transformation as a result of our dealings with transformations in the areas of energy, mobility or other infrastructures. One of my vested interests is to make a contribution to necessary system transformations and the social impacts of these – in my role as a researcher and as a manager of so many committed employees," says Professor Edler.

Fraunhofer Institute spin-offs

The institutes of the Fraunhofer-Gesellschaft 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.

Arioso Systems GmbH

Innovative micro loudspeakers

We will no longer need to learn foreign languages in the future. A small button in the ear, known as a hearable, will soon simultaneously translate every conversation for us. The Fraunhofer Institute for Photonic Microsystems IPMS in Dresden developed an essential component for this: an innovative sound transducer principle for miniaturized headphones. The development, manufacture and marketing of this innovation are being advanced through the spin-off company Arioso Systems.

You wear the small and discreet hearables in your ear and control them using voice commands. In future, they may take over many application areas in Internet communication such as translations, payment functions and other voice-based services. A key aspect, however, is that the electronic components that they contain must be very small and very powerful. This is made possible by the Nanoscopic Electrostatic Drive (NED) technology, which was invented by Fraunhofer IPMS.

The new sound transducer principle no longer contains the conventional membrane. This was broken into strips and integrated into a MEMS silicone chip in the form of numerous bending beams, similar to the strings of a harp. The advantage of silicon technology is the high degree of miniaturization. As a result, the components in the NED loudspeaker take up very little space. Due to the electrostatic drive selected, they will also be more energy-efficient than traditional systems. In addition, the micro loudspeaker delivers very high audio quality.

The Fraunhofer-Gesellschaft is involved in the Arioso Systems start-up and has licensed the NED technology exclusively to Arioso Systems for the "audio" field of application. Furthermore, Fraunhofer IPMS is making its infrastructure available for the development and manufacture of NED micro loudspeakers in small batches of several tens of thousands of units per year.



Clous GmbH

Virtual network accelerates design process

Design processes are time-consuming and costly – particularly when the steps are completed in a linear fashion one after the other, as is usually the case. The Fraunhofer spin-off Clous organizes the collaboration involved in design processes in a completely new way and thus enables companies to achieve faster, more flexible and more efficient engineering.

In the Fraunhofer Institute for Production Systems and Design Technology IPK in Berlin, Claas Blume and Thomas Vorsatz formed an initial robust design from their idea at a start-up boot camp. Under the AHEAD company building program by Fraunhofer Venture, they worked on the final development in terms of the readiness of the team, the market and the product. Clous was then launched on the market in 2020.

The goal of the Clous founders is to make the advantages of the platform economy in engineering usable globally. With this in mind, Clous breaks down the design process into several individual project modules that can be combined with one another using intelligent methods. Instead of the high-level industrial assembly line sequence, Clous uses a virtual network of small processes and interacting players according to the cloud principle. All subprojects are permanently linked, are aligned to one another and are monitored. In this way, many process steps run practically in parallel. The biggest cost factor for a design company, i.e. the time from the idea through to the successful prototype test, is thus reduced significantly.

A further advantage here is that as Clous breaks down the entire project into many smaller micro-projects, companies can also integrate external resources into the construction process without having to disclose the entire development. Intellectual property therefore remains protected while external experts can also participate in the internal innovation processes. In the medium term, Clous intends on becoming a complete platform economy via which the entire value chain can be processed, from procurement right through to production.

In 2020, Clous gained a renowned investor, APX (Axel Springer Porsche GmbH & Co. KG).



CodeShield GmbH

Smart security checks for cloud applications

Firewalls and virus scanners protect software from attackers. However, increasingly they are not enough. Modern cloud applications, in particular, are increasingly exposed to cyber-attacks. The start-up company CodeShield has developed a service that makes it possible to evaluate the security of cloud software and to eliminate security vulnerabilities early on.

The members of the founding team, Manuel Benz, Andreas Dann, Dr. Johannes Späth and Prof. Dr. Eric Bodden, got to know each other during joint research work in Prof. Bodden's specialist group at Paderborn University and at the Fraunhofer Institute for Mechatronic Systems Design IEM. CodeShield, which is a spin-off of the Heinz Nixdorf Institute, Paderborn University and Fraunhofer IEM, started operations in April 2020. CodeShield helps developers to find and eliminate security vulnerabilities in their cloud software. CodeShield provides an interactive visualization of the developed software, its architecture and the data flow within the cloud. Using an integrated security check, developers can therefore quickly identify and resolve critical security vulnerabilities. The technology used at CodeShield is based on the founders' joint research in the area of IT security and code analysis, which makes it possible for the first time to precisely and efficiently identify known and previously undetected vulnerabilities in the program code.

Shortly before SAP and Deutsche Telekom brought out the COVID warning app in the summer, the founding team put it to the test. The source code had already been published, so CodeShield started its analysis. And in fact, two security vulnerabilities set off alarm bells. One of them was categorized by the CodeShield analysis as being particularly relevant. The team informed SAP immediately about the results and risks and thus enabled the developers to eliminate the security vulnerabilities before the app was launched. The library in question was immediately replaced.

The technology behind CodeShield received the Ernst Denert Software Engineering Award in 2019. CodeShield receives funding from the "START-UP transfer.NRW" European funding program and the StartUpSecure program from the German Federal Ministry of Education and Research.



Threedy GmbH

Achieving optimum use of 3D design data

3D models are now indispensable. However, the use of design data is difficult and complex. Simple visualization and complex mixed reality applications require a lot of memory and computing power, fast Internet connections, compatible software and much more. The Fraunhofer Institute for Computer Graphics Research IGD has developed a solution that overcomes all of these hurdles. The aim of the Fraunhofer spin-off Threedy GmbH is to market this platform, called "instant3Dhub."

Instant3Dhub displays CAD data such as design and assembly plans and enables further calculations to be carried out for their applications. The platform therefore supports engineers, technicians and installers in developing new prototypes or in the maintenance of devices, for example. Such software solutions are currently in use in the automotive, aerospace and energy sectors, and also in building information modeling. The four founders, Christian Stein (CEO), Johannes Behr, Maik Thöner and Sascha Räscher have already successfully demonstrated numerous application scenarios in manufacturing or have implemented these in collaboration with customers.

The technology allows data sets of any size to be used across all application and device classes, connected directly with business data and sensors. Due to the intelligent distribution of calculations, complex model data can even be used on low-performance devices. For example, only the geometric parts that are actually visible are loaded and rendered, which speeds up rendering and enables interactive applications even at low bandwidths.

At its market launch in 2020, the company was able to raise starting capital of €1.8 million. The investor group is led by the Industrial Technologies Fund from btov Partners in conjunction with the High-Tech Gründerfonds (HTGF) start-up fund and Fraunhofer.

THREEDY
GmbH

Wiferion GmbH

Contactless energy supply for mobile transportation systems

How do you advance the energy transition in business and industry? By making battery systems so practical and efficient that fossil fuels are no longer worth considering. That is the approach taken by Wiferion in Freiburg.

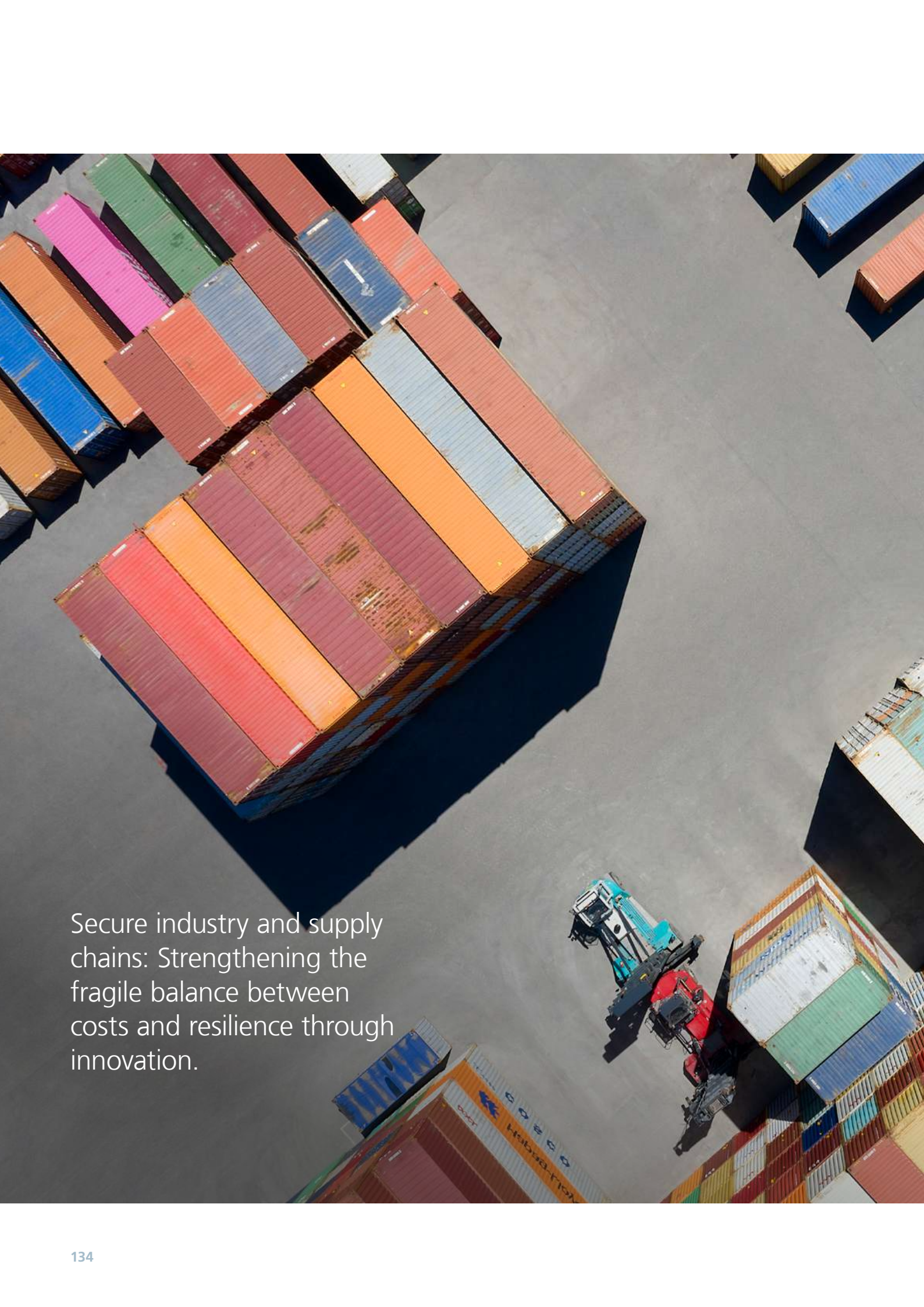
The four founders got to know each other at the Fraunhofer Institute for Solar Energy Systems ISE while working on a research project on the inductive charging of electric cars. The team, comprising Florian Reiners, Benriah Goeldi, Johannes Tritschler and Johannes Mayer, decided to use this technology to tap into the large market of mobile industrial robots and develops wireless charging systems for rechargeable batteries in mobile transport systems. In 2017, they received the Freiburg Innovation Prize and won first place in the "CyberOne Hightech Award Baden-Württemberg" business plan competition in the industrial technologies category. In 2020, Wiferion received the IFOY Award 2020 for Start-up of the Year and the etalink charging system was distinguished as the "Best Product" of the year, receiving both the LogiMAT and Handling Award.

Wiferion develops and distributes inductive fast charging systems for electric vehicles and mobile robots used in industrial settings. Charging takes place by means of an alternating magnetic field. The efficiency of the contactless transmission corresponds to that of high-quality cable connections. The charging process begins automatically as soon as the vehicle reaches the charging point. There are no disruptions to the workflow, as charging is integrated into the process. Industrial electric vehicles can thus be operated efficiently and without any interruption.

Wiferion's customers are manufacturers of mobile robots, forklifts and automated guided vehicles such as KUKA and Magazino. In addition, numerous other fields of application outside of logistics are conceivable in agriculture, shipping and, of course, electromobility.

The collaboration with Fraunhofer ISE was strengthened recently: the parties are jointly working on new storage systems, battery designs, battery management systems and prototypes for supplying clean energy to forklifts and automated guided vehicles (AGVs) in industry.

 **Wiferion**
efficient wireless power



Secure industry and supply chains: Strengthening the fragile balance between costs and resilience through innovation.



Financial report

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Balance sheet at December 31, 2020

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

ASSETS	2020 in €	2020 in €	2020 in €	2019 in € (1000)
A. Non-current assets				
I. Intangible assets				
1. Concessions, industrial property rights and similar rights and assets	11,369,614.64			16,705
2. Advance payments	34,999,188.00			33,440
		46,368,802.64		50,145
II. Property, plant and equipment				
1. Land, land rights and buildings, including buildings on third-party land	1,296,790,603.25			1,237,237
2. Technical plant and machinery	570,624,251.09			494,798
3. Other plant, operating and business equipment	47,846,407.24			45,299
4. Advance payments and assets under construction	493,152,323.40			472,927
		2,408,413,584.98		2,250,261
III. Financial assets				
1. Shares in affiliated companies	92,782.82			93
2. Shareholdings	9,010,126.41			8,487
3. Securities held as non-current assets	8,522,163.36			9,153
4. Other loans	127,500.00			515
		17,752,572.59		18,248
			2,472,534,960.21	2,318,654
B. Current assets				
I. Inventories				
1. Work in progress–	494,664,837.08			455,865
advance payments received	–408,822,141.87			–380,345
	85,842,695.21			75,520
2. Advance payments	–			25
		85,842,695.21		75,545
II. Accounts receivable and other current assets				
1. Trade receivables	201,246,213.68			216,125
2. Receivables from the federal and state governments				
a) relating to base funding	104,249,165.80			103,003
b) relating to project billing, including contract research	226,995,753.47			204,330
c) relating to pension and compensated leave provisions	85,405,400.00			80,601
	416,650,319.27			387,934
3. Accounts receivable from associated companies	10,586,537.85			116
4. Other current assets	128,418,930.34			122,418
		756,902,001.14		726,593
III. Other securities		440,610,674.21		415,312
IV. Cash and cash equivalents		100,210,716.58		91,340
			1,383,566,087.14	1,308,790
C. Prepaid expenses and deferred charges			87,124,251.84	80,942
			3,943,225,299.19	3,708,386
Trust assets			23,017,887.63	21,820

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

EQUITY AND LIABILITIES	2020 in €	2020 in €	2020 in €	2019 in € (1000)
A. Equity				
I. Capital of the non-profit organization				
Carried forward	15,339,755.19			15,288
Retained earnings	47,512.24			52
		15,387,267.43		15,340
II. Restricted reserves				
Carried forward	15,875.00			1,224
Transfers	–			1,211
Allocations	2,950.00			3
		18,825.00		16
			15,406,092.43	15,356
B. Special reserves				
1. License-fee revenue reserve		415,508,285.76		415,508
2. Grants relating to non-current assets		2,460,606,390.82		2,305,946
3. Grants used to finance current assets		324,710,639.34		265,214
4. Present value of deferred income from patent deal		53,577,122.02		64,410
5. To finance restructuring measures		25,000,000.00		–
			3,279,402,437.94	3,051,078
C. Provisions				
1. Provisions for pensions and similar obligations		8,805,400.00		9,101
2. Other provisions		190,201,664.01		187,408
			199,007,064.01	196,509
D. Current liabilities				
1. Trade payables		100,403,673.14		110,589
2. Unappropriated grants from the federal and state governments				
a) relating to base funding	204,528,469.18			194,121
b) relating to project billing	108,061,881.17			99,789
		312,590,350.35		293,910
3. Accounts payable to affiliated companies		186,431.44		651
4. Other current liabilities (of which relating to tax: €9 million; 2019: €22 million)		31,626,826.31		35,579
			444,807,281.24	440,729
E. Total liabilities and equity			4,602,423.57	4,714
			3,943,225,299.19	3,708,386

Trust liabilities

23,017,887.63

21,820

Income statement for the financial year 2020

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

	2020 in €	2020 in €	2020 in €	2019 in € (1000)
1. Revenue from base funding				
1.1 Federal government		1,013,631,336.16		846,647
1.2 State governments		162,298,301.93		157,684
			1,175,929,638.09	1,004,331
2. Revenue from own activities				
2.1 Revenue from research and development activities				
2.1.1 Federal government: Project funding	593,074,459.03			594,857
Contracts	17,979,343.00			22,603
2.1.2 State governments: Project funding	215,690,829.76			183,247
Contracts	2,266,857.81			1,874
2.1.3 Business, industry and trade associations	662,416,338.02			724,417
2.1.4 Research funding organizations and other sources	132,128,176.79			166,616
		1,623,556,004.41		1,693,614
2.2 Other revenue		8,208,451.83		6,528
Total revenue			1,631,764,456.24	1,700,142
2.3 Increase in work in progress		38,799,499.23		8,884
2.4 Other internally constructed and capitalized assets		7,060,969.92		8,964
2.5 Other operating income		34,744,813.43		33,992
2.6 Income from equity investments		2,107,175.47		1,803
2.7 Other interest and similar income		1,525,738.35		2,001
			84,238,196.40	55,644
Total base funding and revenue from own activities			2,891,932,290.73	2,760,117
3. Change in special reserves				
3.1 License-fee revenue reserve				
3.1.1 Allocations		-13,090,684.99		-39,358
3.1.2 Reversals		13,090,684.99		8,758
3.2 Grants relating to non-current assets				
3.2.1 Allocations (capital expenditure)		-475,309,639.44		-481,059
3.2.2 Reversals (depreciation and amortization)		310,052,039.22		291,470
3.3 Grants used to finance current assets		-59,497,075.90		-62
3.4 To finance restructuring measures				
Allocations		-25,000,000.00		-
			-249,754,676.12	-220,251
4. Total income available to cover expenditure			2,642,177,614.61	2,539,866

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

	2020 in €	2020 in €	2020 in €	2019 in € (1000)
Carryover			2,642,177,614.61	2,539,866
5. Cost of materials				
5.1 Expenditure on raw materials and consumables	202,906,017.43			201,661
5.2 Expenditure on purchased research and development services	223,937,646.05			204,510
		426,843,663.48		406,171
6. Personnel expenses				
6.1 Salaries	1,268,900,660.50			1,199,381
6.2 Social contributions and expenses for pensions schemes and for supporting of which for pensions: €63,801,910.34 (2019: 60,605 € (1000))	282,525,190.07			265,919
		1,551,425,850.57		1,465,300
7. Amortization of intangible assets and depreciation of property, plant and equipment		309,117,320.28		288,293
8. Other operating expenses		347,470,036.29		372,523
9. Amortization of financial assets and current marketable securities		6,831,202.38		8,067
10. Interest and similar expenses		439,079.37		668
Total expenditure			2,642,127,152.37	2,541,022
11. Net income for the year (2019: Net loss for the year)			50,462.24	-1,156
12. Transfers from reserves			–	1,211
13. Allocations to reserves			-2,950.00	-3
14. Retained earnings			47,512.24	52
15. Allocation to capital of the non-profit organization			-47,512.24	-52
			–	–

Reconciliation between income statement and performance statement (cash-basis accounting)

Income/receipts	Performance statement in €	Non-profit organization capital in €	Reconciling items in €	Income statement in €
Income/receipts				
from base funding	1,171,125,238.09		4,804,400.00	1,175,929,638.09
from research and development activities	1,664,499,273.88		–40,943,269.47	1,623,556,004.41
from other sources	4,388.24		8,204,063.59	8,208,451.83
Increase in work in progress			38,799,499.23	38,799,499.23
Other internally constructed and capitalized assets	7,060,969.92			7,060,969.92
Other income	44,092,468.35	345,552.25	–6,060,293.35	38,377,727.25
Total income/receipts	2,886,782,338.48			
Change in special reserves				
Grants relating to non-current assets				
Allocations to special reserves (capital expenditure)			–475,309,639.44	–475,309,639.44
Reversals of special reserves (depreciation and amortization)		19,847.81	310,032,191.41	310,052,039.22
Grants used to finance current assets	–59,497,075.90			–59,497,075.90
To finance restructuring measures			–25,000,000.00	–25,000,000.00
Change in grants receivable relating to pension and compensated leave provisions	4,804,400.00		–4,804,400.00	
Total business volume	2,832,089,662.58	365,400.06	–190,277,448.03	2,642,177,614.61

Expenditure/disbursements	Performance statement in €	Non-profit organization capital in €	Reconciling items in €	Income statement in €
Expenditure/disbursements				
Cost of materials	388,032,423.44	51,094.66	38,760,145.38	426,843,663.48
Personnel expenses	1,565,211,388.43	640.00	-13,786,177.86	1,551,425,850.57
Amortization of intangible assets and depreciation of property, plant and equipment		167,966.08	308,949,354.20	309,117,320.28
Other operating expenses	378,536,211.27	95,237.08	-23,891,130.31	354,740,318.04
Expenditure as per the income statement				2,642,127,152.37
Change in special reserves				
To finance restructuring measures	25,000,000.00		-25,000,000.00	
Capital expenditure (current and major infrastructure)	475,309,639.44		-475,309,639.44	
Net income for the year		50,462.24		50,462.24
Total business volume	2,832,089,662.58			
		365,400.06	-190,277,448.03	2,642,177,614.61

Performance statement for individual Fraunhofer entities

Fraunhofer Institute/Research Institution for	Location	Expenses		Income	Base funding ¹
		Operating budget 2020 in € (1000)	Capital expenditure 2020 in € (1000)	Project revenue 2020 in € (1000)	
Fraunhofer ICT Group					2020 in € (1000)
Algorithms and Scientific Computing SCAI	Sankt Augustin	14,964.7	600.3	10,877.3	4,687.7
Applied and Integrated Security AISEC	Garching	11,340.2	657.9	8,234.3	3,763.8
Applied Information Technology FIT	Sankt Augustin	20,679.6	427.9	13,397.8	7,709.7
Cognitive Systems IKS	München	7,061.2	274.2	4,689.7	2,645.8
Communication, Information Processing and Ergonomics FKIE	Wachtberg	9,609.5	104.6	7,318.7	2,400.2
Computer Graphics Research IGD	Darmstadt, Rostock	15,484.5	1,050.1	7,295.9	9,238.7
Digital Media Technology IDMT	Ilmenau, Oldenburg	11,391.0	645.0	7,002.4	5,033.6
Experimental Software Engineering IESE	Kaiserslautern	15,708.7	612.2	12,037.5	4,283.3
Industrial Mathematics ITWM	Kaiserslautern	31,102.7	1,914.4	21,369.1	11,648.1
Intelligent Analysis and Information Systems IAIS	Sankt Augustin	26,370.6	711.7	20,772.3	6,310.0
Medical Image Computing MEVIS	Bremen	11,306.0	122.4	7,313.8	4,109.7
Open Communication Systems FOKUS	Berlin	31,176.9	1,816.3	26,643.4	6,349.8
Optronics, System Technologies and Image Exploitation IOSB	Karlsruhe, Ettlingen, Ilmenau, Lemgo	36,934.3	3,001.7	28,077.5	11,858.5
Secure Information Technology SIT	Darmstadt	7,233.0	230.8	6,406.1	1,057.7
Software and Systems Engineering ISST	Dortmund	6,579.2	196.0	5,638.1	1,137.1
Transportation and Infrastructure Systems IVI	Dresden	13,144.4	2,495.9	12,431.6	3,208.7
Central office of the ICT Group IUK-GS	Berlin	272.6	13.2	152.6	133.2
Total for the Fraunhofer ICT Group		270,359.1	14,874.6	199,658.2	85,575.4

¹ Figures rounded on the basis of actual values.

Fraunhofer Institute/Research Institution for	Location	Expenses		Income	Base funding ¹
		Operating budget	Capital expenditure	Project revenue	
		2020	2020	2020	2020
		in € (1000)	in € (1000)	in € (1000)	in € (1000)
Fraunhofer Group for Innovation Research – INNOVATION					
Center for International Management and Knowledge Economy IMW	Leipzig	9,095.4	310.3	5,689.6	3,716.1
Industrial Engineering IAO	Stuttgart	38,414.6	1,281.6	31,964.1	7,732.1
Information Center for Planning and Building IRB	Stuttgart	8,180.8	72.0	2,297.5	5,954.9
Systems and Innovation Research ISI	Karlsruhe	27,350.2	743.5	20,170.2	7,923.5
Technological Trend Analysis INT	Euskirchen	2,688.4	469.3	2,297.9	860.2
Total for the Fraunhofer Group for Innovation Research – INNOVATION		85,729.4	2,876.8	62,419.4	26,186.8
Fraunhofer Group for Life Sciences					
Biomedical Engineering IBMT	Sulzbach	16,273.0	880.8	12,085.7	5,068.1
Cell Therapy and Immunology IZI	Leipzig, Potsdam-Golm	40,277.9	3,867.1	30,079.1	14,066.0
Individualized and Cell-Based Medical Engineering IMTE	Lübeck	3,319.3	1,175.7	3,557.5	937.5
Interfacial Engineering and Biotechnology IGB	Stuttgart, Leuna	26,468.8	2,959.9	19,736.0	9,692.8
Molecular Biology and Applied Ecology IME	Aachen, Schmallenberg, Frankfurt am Main	41,370.2	3,323.1	31,763.2	12,930.2
Process Engineering and Packaging IVV	Freising, Dresden	26,917.9	3,029.4	20,449.5	9,497.8
Toxicology and Experimental Medicine ITEM	Hannover, Braunschweig, Regensburg	35,728.7	3,873.9	27,429.4	12,173.3
Total for the Fraunhofer Group for Life Sciences		190,355.8	19,110.0	145,100.3	64,365.6
Fraunhofer Group for Light & Surfaces					
Applied Optics and Precision Engineering IOF	Jena	39,682.7	11,741.6	38,960.6	12,463.7
Laser Technology ILT	Aachen	41,326.3	6,238.4	29,464.0	18,100.7
Material and Beam Technology IWS	Dresden	28,437.3	3,535.3	19,308.9	12,663.8
Organic Electronics, Electron Beam and Plasma Technology FEP	Dresden	24,142.9	1,443.8	19,781.3	5,805.4
Physical Measurement Techniques IPM	Freiburg	21,234.3	1,248.4	11,113.5	11,369.2
Surface Engineering and Thin Films IST	Braunschweig	13,290.1	417.1	7,231.4	6,475.8
Total for the Fraunhofer Group for Light & Surfaces		168,113.7	24,624.6	125,859.6	66,878.6

¹ Figures rounded on the basis of actual values.

Fraunhofer Institute/Research Institution for	Location	Expenses		Income	Base funding ¹
		Operating budget 2020 in € (1000)	Capital expenditure 2020 in € (1000)	Project revenue 2020 in € (1000)	
Fraunhofer Group for Microelectronics					2020 in € (1000)
Applied Solid State Physics IAF	Freiburg	25,124.7	3,992.1	18,026.5	11,090.4
Electronic Nano Systems ENAS	Chemnitz	13,881.4	2,282.6	11,284.5	4,879.4
High Frequency Physics and Radar Techniques FHR	Wachtberg	19,714.8	568.3	12,957.7	7,325.5
Integrated Circuits IIS	Erlangen, Nürnberg, Dresden	185,008.0	5,377.5	132,264.0	58,121.5
Integrated Systems and Device Technology IISB	Erlangen	28,320.3	1,113.1	20,375.3	9,058.1
Microelectronic Circuits and Systems IMS	Duisburg	45,792.5	2,815.5	21,535.9	27,072.1
Microsystems and Solid State Technologies EMFT	München	16,348.3	973.7	9,451.3	7,870.7
Photonic Microsystems IPMS	Dresden	48,842.2	2,379.1	36,425.8	14,795.6
Reliability and Microintegration IZM	Berlin, Dresden	37,587.9	1,221.6	28,507.3	10,302.2
Silicon Technology ISIT	Itzehoe	22,058.3	2,899.3	17,474.5	7,483.2
Telecommunications, Heinrich-Hertz-Institut, HHI	Berlin, Goslar	59,958.8	3,961.1	50,838.5	13,081.4
Central office of the Research Fab	Berlin	2,135.7	6.5	1,641.9	500.3
Microelectronics Germany (FMD)					
Total for the Fraunhofer Group for Microelectronics		504,773.1	27,590.4	360,783.2	171,580.3
Fraunhofer Group for Production					
Additive Manufacturing Technologies IAPT	Hamburg	9,161.8	3,166.2	5,508.0	6,820.1
Casting, Composite and Processing Technology IGCV	Augsburg, Garching	16,984.6	3,429.8	15,212.4	5,201.9
Environmental, Safety and Energy Technology UMSICHT	Oberhausen, Sulzbach-Rosenberg	50,287.5	3,584.5	40,866.4	13,005.6
Factory Operation and Automation IFF	Magdeburg	18,585.4	547.9	13,763.1	5,370.2
Large Structures in Production Engineering IGP	Rostock	10,091.9	1,035.8	7,517.3	3,610.3
Machine Tools and Forming Technology IWU	Chemnitz	45,972.3	5,039.7	30,467.8	20,544.2
Manufacturing Engineering and Automation IPA	Stuttgart	62,351.3	4,311.0	48,477.0	18,185.2
Material Flow and Logistics IML	Dortmund, Hamburg	35,154.5	1,752.2	28,366.9	8,539.7
Mechatronic Systems Design IEM	Paderborn	12,446.1	599.4	9,982.3	3,063.3
Production Systems and Design Technology IPK	Berlin	17,311.2	1,485.1	12,703.2	6,093.1
Production Technology IPT	Aachen	30,051.4	1,205.7	21,506.6	9,750.4
Total for the Fraunhofer Group for Production		308,397.9	26,157.2	234,371.0	100,184.0

¹ Figures rounded on the basis of actual values.

Fraunhofer Institute/Research Institution for	Location	Expenses Operating budget 2020 in € (1000)	Capital expenditure 2020 in € (1000)	Income Project revenue 2020 in € (1000)	Base funding ¹ 2020 in € (1000)
Fraunhofer Group for Materials and Components – MATERIALS					
Applied Polymer Research IAP	Potsdam-Golm	25,040.3	3,437.5	15,778.9	12,698.9
Building Physics IBP	Stuttgart, Holzkirchen	29,350.1	1,553.2	19,210.0	11,693.2
Ceramic Technologies and Systems IKTS	Dresden, Hermsdorf	62,472.2	14,573.8	53,486.2	23,559.7
Chemical Technology ICT, Polymer Engineering Department	Pfanztal, Karlsruhe	26,378.0	3,272.3	17,384.6	12,335.7
Energy Economics and Energy System Technology IEE	Kassel	27,150.8	2,681.1	21,721.0	8,111.0
Energy Infrastructures and Geothermal Systems IEG	Bochum	6,755.7	586.2	3,856.3	3,485.6
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	9,531.3	204.6	6,974.5	2,761.3
Manufacturing Technology and Advanced Materials IFAM	Bremen, Dresden, Stade	53,530.5	7,174.4	41,619.0	19,086.0
Materials Recycling and Resource Strategies IWKS	Alzenau, Hanau	7,313.5	34.6	3,098.2	4,249.8
Mechanics of Materials IWM	Freiburg	23,180.7	1,977.8	15,377.4	9,781.0
Microengineering and Microsystems IMM	Mainz	12,865.8	855.2	6,080.7	7,640.2
Microstructure of Materials and Systems IMWS	Halle	23,306.4	2,688.4	18,088.0	7,906.9
Nondestructive Testing IZFP	Saarbrücken	14,203.8	621.1	8,005.0	6,819.9
Silicate Research ISC	Würzburg, Bronnbach, Garching, Bayreuth	25,216.0	815.1	15,192.1	10,839.0
Solar Energy Systems ISE	Freiburg, Halle	91,119.7	13,660.6	87,965.2	16,815.1
Structural Durability and System Reliability LBF	Darmstadt	28,059.9	1,779.8	15,483.0	14,356.7
Wind Energy Systems IWES	Bremerhaven, Kassel	31,599.4	8,948.8	38,315.3	2,233.0
Wood Research, Wilhelm-Klauditz-Institut, WKI	Braunschweig	15,303.0	1,260.0	12,635.4	3,927.5
Central office of the Group MATERIALS V-MAT	Darmstadt	461.7	24.8	43.9	442.6
Total for the Fraunhofer Group for Materials and Components – MATERIALS		512,838.7	66,149.4	400,244.8	178,743.3

¹ Figures rounded on the basis of actual values.

Fraunhofer Institute/Research Institution for	Location	Expenses	Income	Base funding ¹	
		Operating budget	Capital expenditure	Project revenue	
		2020	2020	2020	
Institutes outside of Groups		in € (1000)	in € (1000)	in € (1000)	
Fraunhofer headquarters	München	44,755.6	5,665.9	4,968.9	
Institute Center Birlinghoven	Sankt Augustin	1,039.1	139.2	27.9	
Institute Center Stuttgart	Stuttgart	330.7	42.8	13.6	
General overhead costs		120,057.7	755.4	19,102.5	
Fraunhofer Competence Network Quantum Computing	Ehningen	2,793.8	0.0	0.0	
Total for institutes outside of Groups		168,976.8	6,603.4	24,113.1	
Additional research funding ²					
Defense research					
Applied Solid State Physics IAF	Freiburg	13,495.3	5,006.3	7,774.7	
Chemical Technology ICT, Energetic Materials Department	Pfintztal	15,101.0	1,213.3	4,665.9	
Communication, Information Processing and Ergonomics FKIE	Wachtberg	28,733.0	1,422.1	15,861.9	
High Frequency Physics and Radar Techniques FHR	Wachtberg	17,062.8	2,245.6	7,229.2	
High-Speed Dynamics, Ernst-Mach-Institut, EMI	Freiburg	17,915.9	3,547.6	10,346.0	
Optronics, System Technologies and Image Exploitation IOSB, Ettlingen branch	Ettlingen	22,898.3	2,565.1	16,649.2	
Technological Trend Analysis INT	Euskirchen	7,732.5	464.3	2,824.5	
ATHENE					
Computer Graphics Research IGD	Darmstadt	1,834.8	76.0	0.0	
Secure Information Technology SIT	Darmstadt	11,889.5	507.4	0.0	
Research Fab Battery Cells FFB					
Production Technology IPT, institute branch	Münster	10,572.3	5.8	10,578.2	
Total for additional research funding		147,235.4	17,053.5	75,929.5	
Major infrastructure capital expenditure			270,269.9	87,178.0	
Performance statement		2,356,780.0	475,309.6	1,715,657.1	
Total business volume		2,832,089.7			

¹ Figures rounded on the basis of actual values.

² Research of a long-term nature that falls outside the scope of this regular base funding.

Excerpts from the notes to the financial statements 2020

1. 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, 2020, 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 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 non-current 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 three areas of contract research, additional research funding, and major infrastructure capital expenditure.

Presentation of the annual accounts of the Fraunhofer-Gesellschaft

Annual financial statements of the Fraunhofer-Gesellschaft		Reconciliation with income statement format required by public funding authorities
	Income statement	
	Reconciliation between income statement and performance statement	
Balance sheet	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

2. 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 2.3 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 2020, 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.

Convenience translation of the German independent auditor's report

This is a convenience translation of the German independent auditor's report. Solely the original text in German language is authoritative. The independent auditor's report is based on the balance sheet at December 31, 2020, the income statement for the financial year 2020 and the full notes to the 2020 financial statements and the management report 2020.

INDEPENDENT AUDITOR'S REPORT

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

Audit Opinion

We have audited the annual financial statements prepared by Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., München, comprising the balance sheet at December 31, 2020, the income statement for the financial year from January 1 to December 31, 2020, and the notes to the financial statements, including the presentation of the applied recognition and measurement methods. We have similarly audited the management report of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich, for the financial year from January 1 to December 31, 2020.

The results of the audit confirm our opinion that

- the annual financial statements comply in all material respects with the provisions of the German Commercial Code (HGB) as applicable to large corporate entities, including the supplementary provisions of the organization's statutes, and those of German generally accepted accounting principles (GAAP). Together, this information presents a true and fair view of the organization's net assets and financial position at December 31, 2020, and its operating results for the reporting period from January 1 to December 31, 2020.
- the management report provides a true and fair view of the organization's current operating situation. In all material respects, the management report is consistent with the annual financial statements, complies with the statutory requirements, and provides an appropriate picture of the organization's future opportunities and risks.

In accordance with Section 322 (3) item 1 of the German Commercial Code (HGB), we declare that our audit of the annual financial statements and management report did not lead to any reservation.

Basis for Opinion

We conducted our audit of the annual financial statements and the management report in accordance with Section 317 of the German Commercial Code (HGB) and the generally accepted standards for the audit of financial statements promulgated by the Institute of Public Auditors in Germany (Institut der Wirtschaftsprüfer, IDW). Our responsibilities under those standards are further described below under the heading "Auditors' responsibility for the audit of the annual financial statements and management report." We declare that we are independent auditors as defined by German commercial law and that we exercise our duties in compliance with the relevant professional code of conduct, with no other contacts to or interests in the Fraunhofer-Gesellschaft. It is our considered opinion that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion on the annual financial statements and the management report.

Responsibility of the legal representatives and the Senate for the annual financial statements and management report

The legal representatives are responsible for preparing the annual financial statements in accordance with the provisions of the German Commercial Code (HGB) as applicable to large corporate entities, and for ensuring that they comply with German generally accepted accounting principles (GAAP) and present a true and fair view of the organization's net assets, financial position and operating results. The legal representatives are furthermore responsible for carrying out internal audits to the extent that these are considered necessary to comply with German GAAP, as a basis for preparing annual financial statements in such a way that they are free of material – intentional or unintentional – misstatements.

In preparing the annual financial statements, the legal representatives are also responsible for determining the organization's ability to continue as a going concern, which

includes disclosing any relevant information concerning this matter. They are moreover responsible for applying methods of accounting that allow the organization's continuing existence as a going concern to be assessed, insofar as there are no material or legal circumstances that might contradict this assessment.

Another of the legal representatives' responsibilities is the preparation of a management report, which must be consistent with all material aspects of the annual financial statements, comply with German statutory requirements, provide a true reflection of the organization's financial position, and provide a realistic assessment of the organization's future opportunities and risks. In addition, the legal representatives 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 statements made in the management report.

It is the senate's duty to present the annual financial statements to the General Assembly for approval.

Auditor's responsibility for the audit of the annual financial statements and 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 organization'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 implies a high level of confidence but does not guarantee that an audit conducted in full compliance with the provisions of Section 317 of the German Commercial Code (HGB) and of the generally accepted accounting principles promulgated by the Institute of Public Auditors in Germany (IDW) will always detect a material misstatement when it exists. Misstatements may result from fraud or error and are deemed to be material if it can be reasonably expected that they might individually or severally influence business decisions taken by the reader on the basis of the annual financial statements or management report.

Throughout the audit process, we exercise professional judgement and maintain a neutral but critical attitude. We also

- identify and assess the risks associated with material – intentional or unintentional – misstatements in the annual financial statements and management report, plan and carry out our auditing activities in response to these risks, and collect sufficient, appropriate documentary evidence to substantiate our audit opinion. The risk of not discovering material misstatements is higher in the case of fraud than in the case of error, because this could imply fraudulent collusion, deception, deliberate concealment of facts, false representation, or the failure of internal checks and controls.
- familiarize ourselves with the internal control system and other instruments and measures insofar as they affect the auditing of the annual financial statements and management report, in order to design audit procedures that are appropriate in the given circumstances. However, it is not the purpose of the audit to judge the effectiveness of the organization's control system.
- assess the appropriateness of the accounting principles applied by the legal representatives and the extent to which their estimates and judgments are backed up by documented evidence.
- draw conclusions as to the appropriateness of the accounting principles applied by the legal representatives to determine the organization's ability to continue as a going concern and, on the basis of the evidence, determine whether material uncertainties exist about events or conditions that may cast significant doubt on the organization's ability to continue as a going concern. If our investigations lead to the conclusion that material uncertainties do exist, it is our duty to comment on this fact in our independent auditor's report, providing references to the relevant disclosures in the annual financial statements and/or management report. Alternatively, if such comments are inappropriate, it is our duty to modify our audit opinion accordingly. 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 organization to cease to continue as a going concern.
- verify that the overall presentation, structure and content of the annual financial statements, including the disclosures and the presentation of underlying business transactions and events, comply with German generally accepted accounting principles (GAAP) and present a true and fair view of the organization's net assets, financial position and operating results.

- confirm that the management report concords with the annual financial statements, complies with legal requirements and conveys a true image of the organization's financial situation.
- perform audit procedures on the prospective information presented by the legal representatives in the management report. On the basis of sufficient appropriate audit evidence we evaluate, in particular, the significant assumptions used by management as a basis for the prospective information, and evaluate the proper derivation of the prospective information from these assumptions. The audit opinion does not make specific mention of our findings with regard to prospective information or the data on which they are based. 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 19, 2021

Rödl & Partner GmbH
Wirtschaftsprüfungsgesellschaft, Steuerberatungsgesellschaft

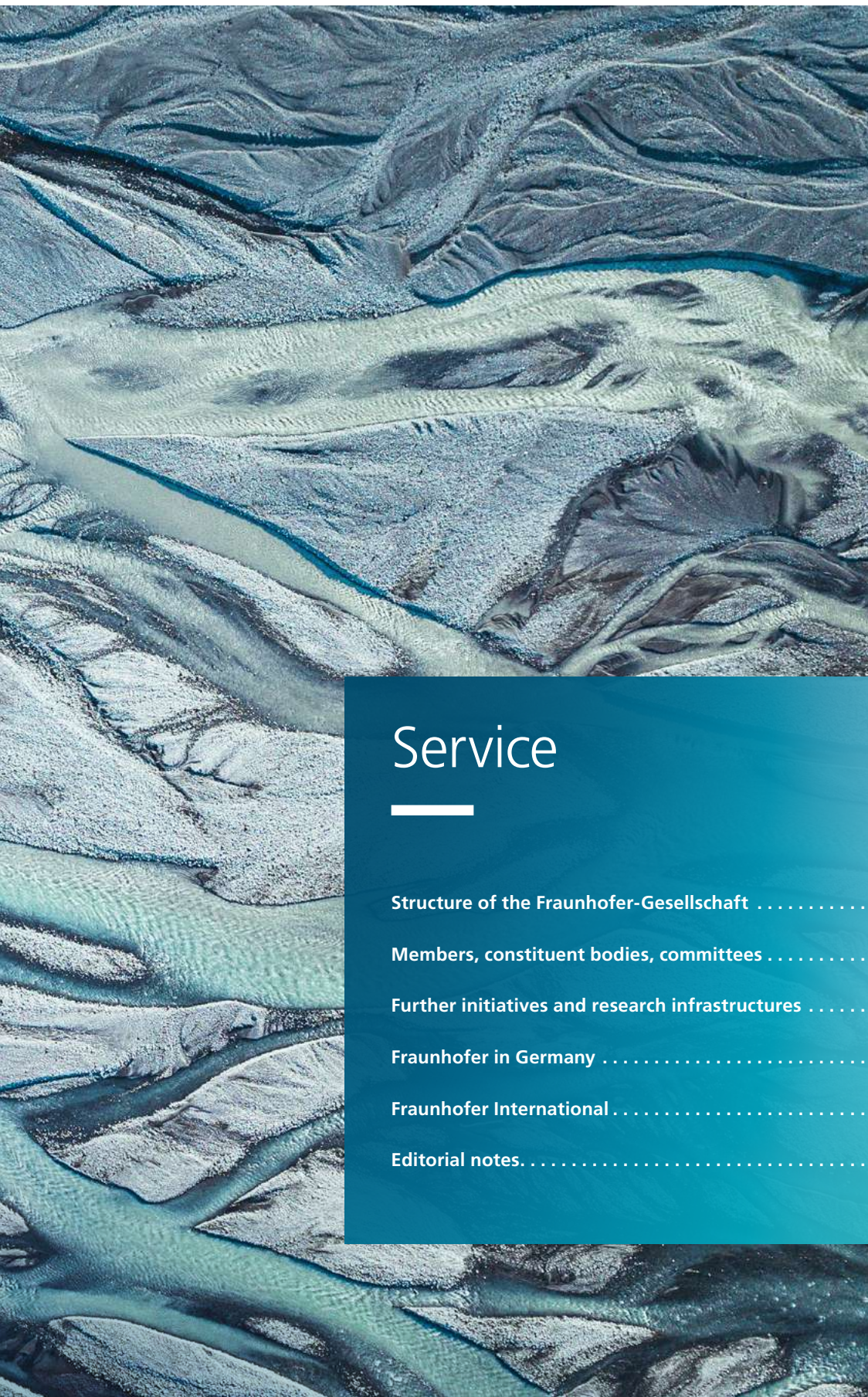
signed Vogel
Wirtschaftsprüfer

signed Hahn
Wirtschaftsprüfer

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.



Resilience against extreme weather events: mitigating the impacts of climate change with sustainable prevention and emergency measures.



Service

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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 within and outside of the organization. It formulates the basic principles of the Fraunhofer-Gesellschaft 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 **75 institutes and research units** 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 into nine **Fraunhofer Groups**, each with a dedicated research focus and tasked with coordinating this research 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.

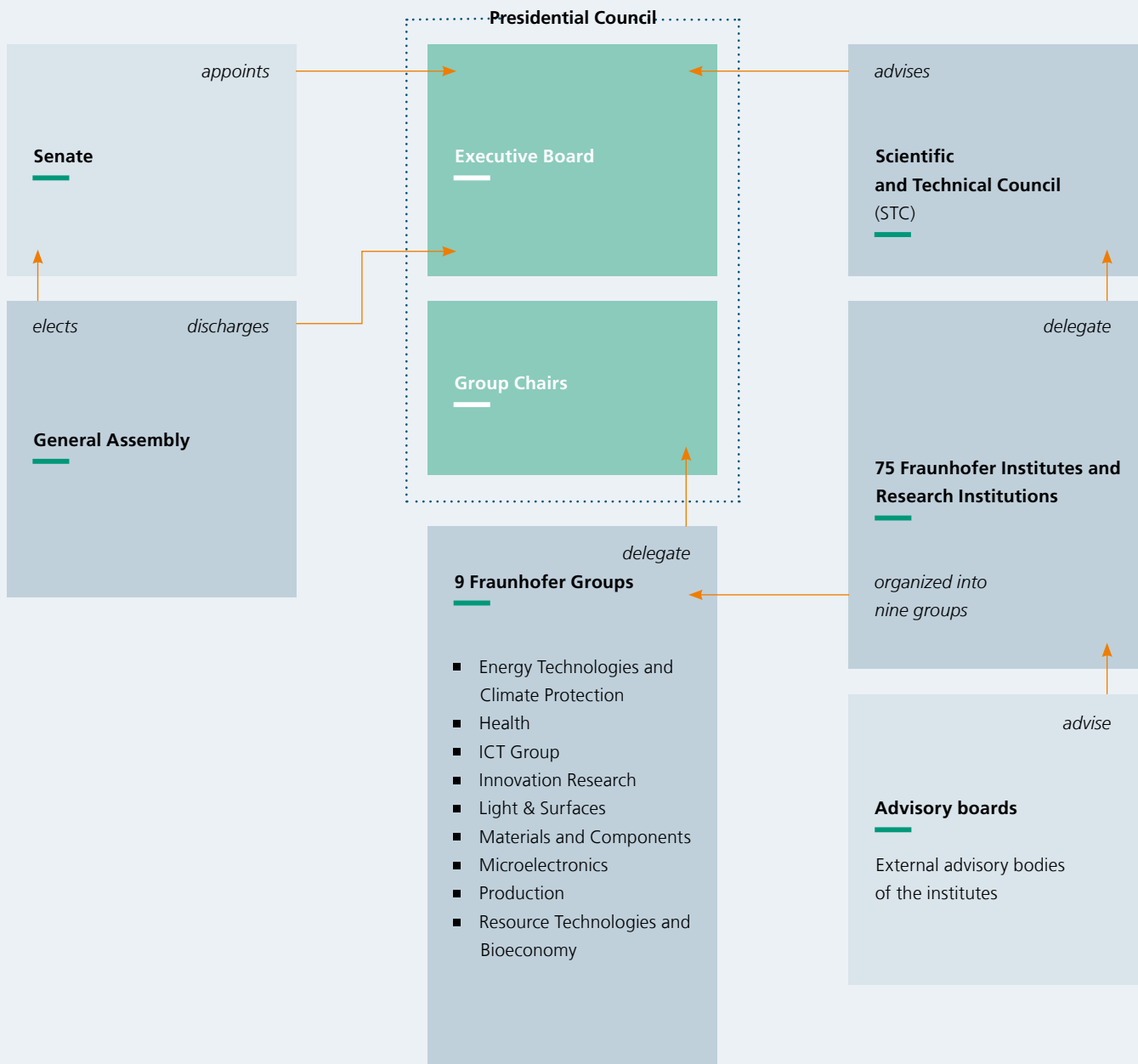
The **Senate** has around 30 members, comprising eminent figures from the worlds of science, industry and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The Senate's duties include appointing members of the Executive Board, defining the outlines of the Fraunhofer science and research policy, and formulating decisions concerning the establishment, transformation, 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 of the institutes and an elected representative of the scientific and technical staff of each institute. The STC advises 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 establishment 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 research focus 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 1158 members, comprising 211 ordinary members, 948 official members and 9 honorary members. Some members have multiple functions.

Honorary members

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Member of the Board of Management, Volkswagen AG, Chairman of the Executive Board, Porsche AG

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Chief Technology Officer and Member of the Managing Board of Siemens AG

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Dr. Sabine Herlitschka
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Former Spokesman of the Executive Board of Diehl Group

Prof. Dr. Wiltrud Treffenfeldt
Former CTO of Dow Europe, Middle East, Africa & India

Grazia Vittadini
Airbus Chief Technology Officer & Member of the Airbus Executive Committee

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Anna-Katharina Wittenstein
Member of the Management Board of WITTENSTEIN SE

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MinDirig
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Dr. Volker Saß
Head of the "Science Planning and Research Promotion" department of the Bremen Senator for Science and Ports

Senate

Members representing science, industry and public life

Prof. Dr.-Ing.
Heinz Jörg Fuhrmann
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IML

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Chair of the German Council
of Science and Humanities

MinDirig Dr. Manfred Wolter
Bavarian Ministry of
Economic Affairs, Regional
Development and Energy

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 181 members,
109 of whom are institute
directors or senior managers,

while 72 are elected repre-
sentatives of the scientific
and technical staff of each
institute

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

Presidential Council

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

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Fraunhofer Group for
Innovation Research

Prof. Dr. Karsten Buse
Fraunhofer Group for
Light & Surfaces

Prof. Dr.-Ing.
Welf-Guntram Drossel
Fraunhofer Group for
Production

Prof. Dr. techn. Dr.-Ing. eh.
Dieter W. Fellner
Fraunhofer ICT Group

Prof. Dr. Peter Gumbsch
Fraunhofer Group for
Materials and Components

Prof. Dr.-Ing.
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Fraunhofer Group for
Microelectronics

Prof. Dr. Dr. Gerd Geißlinger
(acting)
Fraunhofer Group for Health

Prof. Dr.-Ing.
Eckhard Weidner (acting)
Fraunhofer Group for
Resource Technologies and
Bioeconomy

Prof. Dr.
Hans-Martin Henning (acting)
Fraunhofer Group for Energy
Technologies and Climate

Member of Presidential Council from segment acting in an advisory capacity

Prof. Dr.-Ing. Jürgen Beyerer
Fraunhofer Segment for
Defense and Security VVS

Executive Board

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Prof. E. h. Dr.-Ing. E. h. mult.
Dr. h. c. mult.
Reimund Neugebauer
(President)

Prof. Dr. rer. nat.
Ralf Boris Wehrspohn

Prof. Dr. rer. publ. ass. iur.
Alexander Kurz

Dipl.-Kfm. Andreas Meuer

List of committee members
as of January 31, 2021

Further initiatives and research infrastructures

Impact goals

The purpose of 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 based on a cooperative interdisciplinary approach:

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

Fraunhofer Strategic Research Fields

The Fraunhofer Strategic Fields of Research are the key areas that make up the Fraunhofer-Gesellschaft research portfolio. Taking relevance, strategy and priorities into account, Fraunhofer has firmly positioned itself in the following research fields:

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

Fraunhofer Groups

Within the Fraunhofer model, the Fraunhofer Groups are places of solidarity that enable the shared utilization of resources. Their mission is to safeguard and advance scientific excellence in their respective areas of research.

In 2020, a portfolio process was carried out at each Fraunhofer Group to document and structure their expertise. Based on these results, it was decided to restructure the groups. In particular, changes were made in the Life Sciences Group, which was broken down to create three new groups. Institutes with goals that involve the security of people, society and the state coordinate their activities within the Fraunhofer Segment

for Defense and Security VVS. Expertise-based groups are currently active in the following fields:

- Energy Technologies and Climate Protection
- Health
- ICT Group
- Innovation Research
- Light & Surfaces
- Materials and Components
- Microelectronics
- Production
- Resource Technologies and Bioeconomy

Lead-market-oriented alliances

With **lead-market-oriented alliances**, Fraunhofer has created a structure for cooperative technology transfer platforms for the institutes with the aim of providing industry customers with optimal access to pooled, cross-institute research services and systemic solutions. Eight sectors with major relevance for the innovative strength of Germany and Europe were defined as lead markets, each of which is addressed by a lead-market-oriented alliance.

- Plant, mechanical and vehicle engineering
- Construction industry
- Energy sector
- Healthcare sector
- Mobility sector
- Digital economy
- Chemical industry
- Agriculture and food industry (starting 2021)

Fraunhofer Clusters of Excellence

Fraunhofer leverages the potential synergies that exist between individual institutes based on their research focus areas by means of strategic networking across internal programs and projects. The aim is to pool together institutes with complementary profiles and/or to pool together the specific expertise of institutes that are active in the same field in order to create a leading position.

The Fraunhofer Clusters of Excellence were introduced in 2017 as a new funding initiative. Their purpose is to bring a specific field of research to a wider international audience. The clusters support long-term collaboration between Fraunhofer Institutes as part of strategic roadmaps aimed at creating innovations that are of systemic importance and have the potential to be disruptive. They are driven by a specific research focus for an initial duration of five years and are led by a responsible management team; they are integrated into existing infrastructures and are usually spread across several locations. They therefore operate like a virtual institute. An interim evaluation of all six current Clusters took place in March 2021.

- 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. Working together, Fraunhofer Institutes and Fraunhofer partners quickly turn scientific ideas into marketable products.

Current lighthouse projects

- 6G SENTINEL – Next-generation mobile communications
- Future Proteins – High-quality protein worldwide
- ALBACOPTER – Vertical glider experiment
- ShaPID – Green deal for the chemical industry
- WASTE4FUTURE – From waste to raw material
- EVOLOPRO – Evolutionary self-adaptation of complex production processes and products
- ElKaWe – Electrocaloric heat pumps
- MaNiTU – Materials for sustainable tandem solar cells with extremely high conversion efficiency
- SWAP – Heterogeneous, workload-optimized robot teams and production architecture
- COGNAC – Cognitive agriculture
- MED²ICIN – Medical data driving an integrated cost-intelligent model
- ML4P – Machine learning for production

- QUILT – Quantum methods for advanced imaging solutions
- Qmag – Quantum magnetometry
- ZEPOWEL – Towards zero power electronics
- eHarsh – Sensor systems for extremely harsh environments

Completed lighthouse projects

- Next generation additive manufacturing – futureAM
- Digital manufacturing – Innovative integration of digital printing and laser processes for mass customization – Go Beyond 4.0
- 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: Transforming maximum profit from minimum capital investment into maximum 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

As a branch of the Fraunhofer Institute for Production Technology IPT, the Research Fab Battery Cells FFB at the Münster location is to become the German development center for battery cell production. The aim is to accelerate the process of innovating and commercializing production technologies for existing and future cell formats. The collaboration partners are RWTH Aachen and the Münster Electrochemical Energy Technology (MEET) Battery Research Center at the University of Münster.

Research Fab Microelectronics Germany (FMD)

As the largest cross-location R&D association for micro- and nanoelectronics in Europe, Research Fab Microelectronics Germany (FMD) offers a unique range of expertise and infrastructure. FMD thus bridges the gap between basic research and customer-specific product development. As a one-stop shop, it offers industry customers tailor-made technology and system solutions that encompass the entire value chain. It gives SMEs and start-ups easier, more comprehensive access to advanced technologies and to pooled equipment and technologies for testing new products. Eleven Fraunhofer Institutes from the Fraunhofer Group for Microelectronics collaborate with two Leibniz Institutes: the Ferdinand-Braun-Institut,

Leibniz-Institut für Höchstfrequenztechnik (FBH) and the Leibniz Institute for Innovations for High Performance Microelectronics (IHP).

Cybersecurity Training Lab

Nine Fraunhofer Institutes and Research Institutions and selected universities of applied science across Germany have joined forces as part of the continuing education program Learning Laboratory Cyber Security. In high-grade laboratories with real work environments, training participants can experience the effects of hacking attacks first hand and practice defense strategies, for example, on the control center of a power plant or on a production line used in industrial manufacturing.

Max Planck School of Photonics

The German Federal Ministry of Education and Research (BMBF) is funding the Max Planck Schools as a new type of graduate education. The Max Planck School of Photonics is lead-managed by the Fraunhofer Institute for Optics and Precision Engineering IOF in Jena. Collaboration partners also include the Fraunhofer Institute for Laser Technology ILT, the Max Planck Institute for Biophysical Chemistry (BPC), the Max Planck School of Photonics (MPL), the Max Planck Institute of Quantum Optics (MPQ), the Deutsches Elektronen-Synchrotron (DESY), the Helmholtz Center for Heavy Ion Research in Jena (GSI HIJ) and the Leibniz Institute of Photonic Technology (IPHT).

National Research Center for Applied Cybersecurity ATHENE

There are over 500 scientists researching cybersecurity under the umbrella of ATHENE. Apart from an emphasis on IT and engineering, ATHENE also considers interdisciplinary questions from the fields of law, economics, psychology and ethics. It is strongly focused on real-world applications and covers everything from technology transfers through to the establishment of start-ups. For example, ATHENE is researching how Germany's critical infrastructures (power, transportation, etc.) can be protected and how IT systems can be secured in the long term, even in the face of new technologies such as quantum computers. It also continuously identifies important, application-oriented issues affecting cybersecurity and privacy.

ATHENE is a research center of the Fraunhofer-Gesellschaft (Institutes for Secure Information Technology SIT and for Computer Graphics Research IGD) with the participation of the Technical University of Darmstadt and Darmstadt University of Applied Sciences. The National Research Center provides an innovative collaboration model for university and non-university research that enables cutting-edge research for the benefit of society, business and the state.

High-Performance Centers

High-Performance Centers provide the framework needed to align university and non-university research with business. Universities, higher education institutions, Fraunhofer Institutes and other non-university research institutions work closely with businesses and stakeholders from civil society at a single location to carry out research on specific topics in order to rapidly implement the latest innovations in a practical way. High-Performance Centers provide best-of-breed, cross-organizational, practical infrastructure, vocational training programs and expertise. They bring together like-minded partners and provide the guidance needed to bring their innovations to the market. The concept of high-performance centers has already been established at 16 locations across 10 German federal states:

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

International initiatives

Fraunhofer Innovation Platform for the Water-Energy-Food Nexus, Stellenbosch

In February 2020, a collaborative project began at Stellenbosch University in South Africa to advance research and technologies in the water, energy and food sectors. South Africa's water supply is under increasing strain, particularly due to climate change and associated extreme weather events as well as population growth. The new Fraunhofer Innovation Platform (FIP) will bring together the collaboration partners' knowledge, expertise and technologies to develop integrated solutions in the areas of water treatment, security, use and management. The Fraunhofer Institutes for Interfacial Engineering and Biotechnology IGB, for Solar Energy Systems ISE and for Optonics, System Technologies and Image Exploitation IOSB are involved in the collaboration.

“Fraunhofer Innovation Platform” is a new funding program that supports the establishment of temporary research units at a university or research institution outside of Germany.

Fraunhofer USA

The research units in the USA have now been amalgamated into three large regional centers:

- Fraunhofer USA Center Midwest – Key areas of surfaces, materials, microelectronics
- Fraunhofer USA Center Northeast – Key areas of production technology, energy technology, medical technology
- Fraunhofer USA Center Mid-Atlantic – Key areas of information technology, data security, artificial intelligence

Further initiatives

International Data Spaces Association

The data economy has proven to be an essential part of the digitalization of companies – across all domains. When it comes to the digital use of data, both producers and owners of data often see the risks inherent in handing over control, and thus the strategic value of their data resources. The international Data Spaces Association (IDSA) provides the necessary data infrastructure for this by enabling data providers to share data while maintaining data sovereignty. It now has over 100 members both within and outside of Germany.

Proof-of-concept initiatives for translational medical research

Through the proof-of-concept initiative (PoC), the Helmholtz Association, the Fraunhofer-Gesellschaft and Deutsche Hochschulmedizin are testing a format for promoting the quick and efficient transfer of pre-clinical research to clinical development. Clinical proof of the effectiveness of an innovative method of therapy or diagnostics (proof of concept, or PoC for short) is generally an important prerequisite for the successful transfer of projects to businesses where they can be further developed and made ready for the market.

Project centers

The interdisciplinary Fraunhofer Project Centers (FPCs) enable Fraunhofer Institutes to create local hubs focused on a single location and a specific area of research. The aim is to enter into a long-term engagement with the location in order to establish a specific area of focus.

- Lightweight Construction and Electromobility, Wolfsburg
- Microelectronic and Optical Systems for Biomedicine, Erfurt
- Energy Storage and Management Systems ZESS, Braunschweig
- Stem Cell Process Engineering, Würzburg

Main locations ●

Other locations ○



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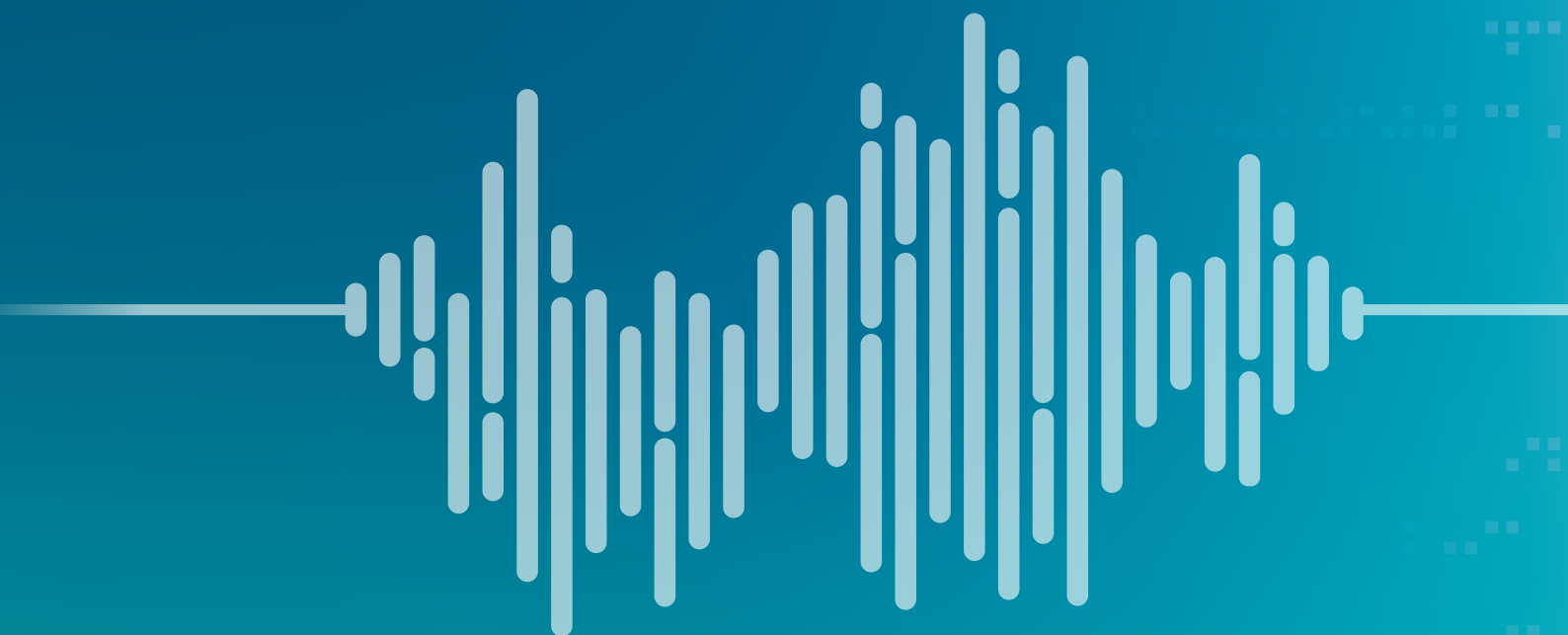
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