Fraunhofer

2022 Annual Report

Political Sovereignty through Economic Competitiveness

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, based in Germany, is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, the Fraunhofer-Gesellschaft supports science and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work with partners from industry and government to turn pioneering ideas into innovative technologies, coordinate and implement system-relevant research projects and strengthen the German and European economies with a commitment to value creation that is based on ethical values. International collaboration with outstanding research partners and companies from around the world brings the Fraunhofer-Gesellschaft into direct contact with the most prominent scientific communities and most influential economic regions.

Founded in 1949, the Fraunhofer-Gesellschaft now operates 76 institutes and research units throughout Germany. Currently around 30,800 employees, predominantly scientists and engineers, work with an annual research budget of about €3.0 billion, €2.6 billion of which is designated as contract research. Around two thirds of Fraunhofer contract research revenue is generated from industry contracts and publicly funded research projects. The German federal and state governments contribute around another third as base funding, enabling the Fraunhofer institutes to develop solutions now to problems that will drastically impact industry and society in the near future.

The impact of applied research goes far beyond the direct benefits to the client. Fraunhofer institutes strengthen companies' performance and efficiency and promote the acceptance of new technologies within society while also training the future generation of scientists and engineers that the economy so urgently requires.

As a scientific organization, the key to our success is highly motivated employees engaged in cutting-edge research. Fraunhofer therefore offers its researchers the opportunity to undertake independent, creative and, at the same time, targeted work. We help our employees develop professional and personal skills that will enable them to take up positions of responsibility within Fraunhofer itself or at universities, within industry and in society at large. Students involved in projects at Fraunhofer institutes have excellent career prospects on account of the practical vocational training they enjoy and the opportunity to interact with contract partners at an early stage in their career.

The Fraunhofer-Gesellschaft is a recognized non-profit organization named after Joseph von Fraunhofer (1787–1826), an illustrious researcher, inventor and entrepreneur hailing from Munich.

Figures as of: March 2023
www.fraunhofer.de/en.html

Publishing notes

Editorial team
Josef Oskar Seitz
(editor in chief)
Tanja Schmutzer
(managing editor)
Eva Bachmann
Mandy Bartel
Anja Richter

Design
Silke K. Schneider

Title page: Fraunhofer/iStock

Editorial address
Fraunhofer-Gesellschaft
Hansastrasse 27 c
80686 München, Germany
Josef Oskar Seitz
Science Communications
Corporate Media
Phone +49 89 1205-1310
josef.seitz@zv.fraunhofer.de

2022 Annual Report

Foreword

Ladies and gentlemen,

Society as a whole faced multiple challenges in 2022. Nevertheless, the Fraunhofer-Gesellschaft is on a scientifically excellent and economically stable path. Our business volume increased by 5 percent to around €3.0 billion last year. This is in large part due to the great commitment, hard work and fruitful ideas of the approximately 30,800 people currently employed at the Fraunhofer-Gesellschaft.

Although Germany is now managing one of the most difficult crises in the post-war era, we are still facing the critical challenge to advance the transformation of the economy to climate neutrality. Sustainable innovations in the energy sector are the best way to increase productivity in the context of climate targets, to reduce dependency on fossil fuels and hence to secure Germany's competitiveness as a technological powerhouse on a long-term basis.

At the same time, increasing and expanding domestic energy production provides opportunities for OEMs to re-establish and relocate in Germany and Europe. This is the case, for example, for photovoltaic production, manufacturing capacities for wind turbines or electrolysis operations for the production of green hydrogen. By pooling its scientific expertise in a targeted manner, the Fraunhofer-Gesellschaft has already been successfully conducting research projects on resource efficiency and climate innovations for years. An example of excellent energy research that can accelerate the expansion of renewable energies in the short term is highly efficient solar cells. Fraunhofer researchers have been able to increase the efficiency of the best solar cell to date to 47.6 percent.

Over the medium term, green hydrogen offers great potential and is regarded as an important part of the future energy mix. The first milestone in hydrogen research was achieved in 2022: enerPort II. This will be Europe's first completely climate-neutral container terminal powered by hydrogen and is being built in Duisburg. In September, the H2GO — National Action Plan for Fuel Cell Production was also launched to develop highly scalable industrial fuel cell production for heavy-duty transport.

The Fraunhofer-Gesellschaft has taken steps to secure its future by successfully establishing the new executive board structure, which now comprises five executive board units. I am also delighted to welcome Hildegard Müller, president of the German Association of the Automotive Industry (VDA), as the new chair of the Fraunhofer senate.

As a team, I believe that we have what it takes to develop and strengthen the Fraunhofer-Gesellschaft's capabilities and what it contributes to keeping the German and European economies competitive.

Sincerely,

Reimund Neugebauer
President of the Fraunhofer-Gesellschaft until May 25, 2023

Photo: Stefan Obermeier/Fraunhofer

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The executive board

Prof. Reimund Neugebauer
President of the Fraunhofer-Gesellschaft until May 25, 2023

Reimund Neugebauer is a professor of machine tool design at the Chemnitz University of Technology. Having held various leadership roles in the mechanical engineering industry, he set up what is now the Fraunhofer Institute for Machine Tools and Forming Technology IWU in 1991. He was elected Fraunhofer President in 2012. During his tenure, the Fraunhofer-Gesellschaft has consolidated its position as a driver of innovation in the German economy. The number of employees has grown from around 20,000 to around 30,800 today and the number of Fraunhofer institutes and research units has increased from 64 to 76. New research fields such as quantum and hydrogen technologies and, most recently, nuclear fusion have been successfully established.

Prof. Alexander Kurz
Executive Vice President for Innovation, Transfer and IP Management

Alexander Kurz has been an executive vice president of the Fraunhofer-Gesellschaft since 2011: first for the sectors of Human Resources, Legal Affairs and IP Management, and, since 2022, for Innovation, Transfer and IP Management. He initially worked as a lawyer after completing his legal training. From 1989, he held management and board positions for major research organizations such as CERN in Geneva and the Karlsruhe Institute of Technology (KIT), where he was actively involved in its foundation as a board member. He has also been an honorary professor at the German University of Administrative Sciences Speyer since 2014.

Elisabeth Ewen
Executive Vice President for Human Resources, Corporate Culture and Legal Affairs

Elisabeth Ewen is a fully qualified lawyer with an additional qualification in administrative and labor law. After graduating, she worked as a lawyer in the HR department of the German Aerospace Center (DLR) before she became director of human resources at GMD – Forschungszentrum Informationstechnik GmbH. She came to the Fraunhofer-Gesellschaft with the integration of the company GMD – Forschungszentrum Informationstechnik GmbH. She has held several management positions in human resources at the Fraunhofer-Gesellschaft, most recently as director of human resources. Elisabeth Ewen has been on the executive board of the Fraunhofer-Gesellschaft since August 2022.

Prof. Axel Müller-Groeling
Executive Vice President for Research Infrastructures and Digital Transformation

Axel Müller-Groeling is a professor at Kiel University. The physicist and manager has conducted research at several renowned institutes and research organizations in Germany, France and Canada. He worked as a management consultant and was also a co-founder and executive vice president of an international, publicly listed photovoltaic group before becoming head of the Fraunhofer Institute for Silicon Technology ISIT in Itzehoe in 2016. He then also became head of the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg. He has been on the executive board of the Fraunhofer-Gesellschaft since August 2022.

Dr. Sandra Krey
Executive Vice President for Finances and Controlling

Sandra Krey studied business administration and earned her doctorate at Friedrich-Alexander-Universität Erlangen-Nürnberg. She held an auditing position at KPMG before she joined the MAN corporation in Munich in 2002. There she held various leadership positions in accounting and controlling. Most recently, she was senior vice president of Accounting and Finance Processes at MAN Truck & Bus SE and, at the same time, was managing director of the MAN Shared Services Center in Poznań, Poland. Sandra Krey has been on the executive board at the Fraunhofer-Gesellschaft since August 2022.

Photos: Stefan Obermeier/Fraunhofer

2022 management report

Fraunhofer-Gesellschaft — key data for 2022 (in € million)

	2021	2022		Change
Total business volume	**2,915**	**3,049**	**+134**	**+5%**
Contract research	2,518	2,615	+97	+4%
Additional research funding	163	245	+82	+50%
Major infrastructure capital expenditure	234	189	–45	–19%
Business volume by budget	**2,915**	**3,049**	**+134**	**+5%**
Operating budget	2,445	2,567	+122	+5%
Capital expenditure[1]	470	482	+12	+3%
Project revenue	**1,858**	**2,083**	**+225**	**+12%**
Contract research	1,738	1,907	+169	+10%
of which industrial revenue	723	787	+64	+9%
of which public-sector revenue[2]	1,015	1,120	+105	+10%
Additional research funding	73	145	+72	+99%
Major infrastructure capital expenditure	47	31	–16	–34%

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

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

Strategy and operating environment

Profile of the Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft is the world's leading applied research organization: Since its foundation in 1949, Fraunhofer institutes have been strengthening the competitiveness of business and innovation in Germany and Europe. Fraunhofer's comprehensive range of solutions for industry and policymakers has an impact across industries. As such, the Fraunhofer strategic research fields provide a deliberate and dynamic impetus for future markets. The Fraunhofer-Gesellschaft is also a key player in making Germany a center of innovation. Its activities increase the effects of investments in the economy and create jobs in Germany, while skilled workers earn qualifications and modern technology becomes more socially acceptable.

In 2022, around 30,350 people, predominantly scientists and engineers, were employed across 76 institutes with an annual research budget of around €3.0 billion, €2.6 billion of which is designated as contract research. Around two thirds of Fraunhofer contract research revenue is generated from industry contracts and publicly funded research projects. The German federal and state governments contribute around another third as base funding, enabling the Fraunhofer institutes to develop solutions now to problems that will drastically impact industry and society in the near future. contract research is the most important business focus. Fraunhofer is a particularly important supplier of innovative know-how for small and medium-sized enterprises. Fraunhofer also contributes to the success of missions in key technologies for society as a whole. Fraunhofer is an attractive and established player in public-private partnerships. At an organization-wide level, Fraunhofer identifies innovative business units and trending technologies with major market potential and significant relevance to society and advances them through in-house research programs.

Each individual Fraunhofer institute and research institution develops its own business units and core areas of expertise on the basis of its immediate market environment and its links with the wider scientific community. Although the institutes operate as separate profit centers, they are not autonomous legal entities. The institutes also cooperate in research facilities and partnerships to capitalize jointly on certain business units or sectors. Fraunhofer associations are currently finalizing portfolio coordination, which includes all organizational units.

Internal change processes support the transformation

Just like other companies and organizations, the Fraunhofer-Gesellschaft was affected by the global events of the **war in Ukraine** and the associated energy scarcity, as well as the **effects of the COVID-19 pandemic** in 2022. At the same time, Fraunhofer organized two **comprehensive internal change processes** with the introduction of SAP and the implementation of a new executive board structure.

All administrative data and business processes of the Fraunhofer-Gesellschaft have been transferred to and implemented on the SAP system landscape since the start of 2022. This comprehensive change process, with a total of 46 SAP solutions, 7 partner solutions and 40 SAP cloud applications, is the largest solution package in the history of the SAP Group. During the hypercare phase in the first few months, the Fraunhofer executive board created a high-level group of institute management and technical experts. This ensured operations could commence and the SAP system landscape could be used, while commissioning solution processes were prioritized and problems were resolved. Since the changeover in January 2022, ongoing operations have been characterized by constant adaptations, fluctuation and automation. The aim of this is to stabilize the operation and use of the SAP system landscape and to continuously improve business process mapping. Fraunhofer accelerated business process orientation in order to achieve this. A team was created for each business process and these

teams consisted of representatives from the institutes and the headquarters.

The **executive board structure was also adapted to the development of the Fraunhofer-Gesellschaft** in 2022. In the last ten years, the number of employees has increased from 22,000 to 30,350, while the budget increased from almost €2 billion to about €3 billion. The new structure supports the thematic focus of the executive board units so that internal synergies can be leveraged in a targeted manner. Fraunhofer has moved from four to five executive board units with the introduction of a new unit: "Research Infrastructures and Digital Transformation". This unit will systematically address the large internal research infrastructures, construction activities, purchasing, SAP-based digital transformation and the development of comprehensive knowledge management. At the same time, the departments of "Innovation, Transfer and IP Management", "Human Resources, Corporate Culture and Legal Affairs" and "Finance and Controlling" were reassigned. The "Corporate Strategy, Research and Communications" department remains in place.

Fraunhofer has had to react vigorously to the supply chain disruption that has continued since the beginning of the COVID-19 pandemic and to the more difficult global energy supply situation since the start of the war in Ukraine. In order to contribute to jointly **overcoming the energy crisis**, Fraunhofer explored and, if possible, implemented all possibilities for short-term energy savings at the institutes. The measures for the **Fraunhofer climate neutral by 2030** project were also intensified. The executive board approved activities in the construction and operation of its properties that hold great potential for CO_2 savings in the medium to long term in order to achieve this ambitious goal. For example, **selected pilot institutes** are currently working on **transformation concepts** in order to lead the properties to climate neutrality and reduce dependence on gas imports. In the climate fund program, projects that support the institutes in achieving potential short-term energy consumption savings and in finding options for action for a reliable and resilient supply of energy from renewable sources in the medium term were approved.

Fraunhofer also initiated an increase in **data security** resilience on the back of a phishing attack on a Fraunhofer institute. The attackers gained access to the system, encrypted sensitive data and then tried to extort a ransom for the decryption. The Fraunhofer executive board took all necessary measures to deal with this incident. A decision was taken in close coordination with the law enforcement authorities not to comply with the ransom demand. A large part of the data, and thus the institute's ability to work, was able to be restored. As a result of the cyber attack, the executive board created a taskforce to guard against future attacks. This taskforce includes experts from the relevant Fraunhofer institutes who work with the information security department at the headquarters to plan and implement specific measures to further **improve Fraunhofer's cyber resilience**. The executive board has added more personnel to the information security department at the headquarters to assist with this and has started a project to further develop cyber security.

With regard to security and resilience research, the **Fraunhofer Center for the Security of Socio-Technical Systems SIRIOS** was launched in Berlin in 2022. In addition to four centers that are already operational, Fraunhofer is using this format to see if one unit managed by several institutes can combine its selected research expertise at a joint office in order to jointly develop new business units. The corresponding specific technical infrastructure will be set up at the new joint office for this purpose. The new Fraunhofer SIRIOS focuses on simulating and transferring research findings on public security. Under the umbrella of the center, four Fraunhofer institutes are establishing a virtual research, testing and training environment for security authorities, rescue forces and operators of critical infrastructure. The aim is to research the complex interaction between technology and people in modern societies and make it safer.

Science policy framework

2022 was a year of several political upheavals that led to new trends in science policy. One of the challenges for the Fraunhofer-Gesellschaft was to build resilient relationships with the key players in the new government coalition of SPD, Greens and FDP: As such, the Fraunhofer-Gesellschaft held about 100 **meetings with selected stakeholders from the legislative and executive branches**. The discussions with decision-makers from federal ministries and members of the German Bundestag revolved around topics relating to science, innovation and economic policy that are also relevant to Fraunhofer.

In the 20th legislative period of the German Bundestag, the Fraunhofer-Gesellschaft is represented on the **Future Council (Zukunftsrat)** by its president, Prof. Reimund Neugebauer. The Future Council, initiated and headed by Federal Chancellor Olaf Scholz, serves as a central innovation policy advisory board to the German federal government on relevant issues in science and research policy. The Future Council analyzes new developments, findings and trends in the innovation life cycle and draws up proposals to improve the resilience and technological sovereignty of key technology. The aim is to harness the potential from research and companies for Germany as a business/industrial location and manage the transition towards a social-ecological market economy as well as possible. The steering committee is chaired by Prof. Henning Kagermann, chair of the acatech advisory board.

In 2022, the Fraunhofer president, alongside the chairman of the executive board of BASF SE, Dr. Martin Brudermüller, chaired the "Strengthening electrolyzer production and use in Germany" task force and was a member of the "Innovation potential of AI-based robotics" task force.

The German Chancellor also initiated the **Transformation Alliance**, which was a guiding dialogue between the German federal government and leaders from business, trade unions, associations, science and civil society to create a reliable framework for Germany's transformation process. Securing a reliable, sustainable and affordable energy supply for Germany was the overarching objective of the second meeting of this alliance in 2022. At this meeting, Fraunhofer president Prof. Reimund Neugebauer presented a roadmap with three partial sub-goals: using domestic renewable energy efficiently and extensively; building a hydrogen economy; and operating a networked energy system intelligently.

The key science policy projects of the German Federal Ministry of Education and Research (BMBF) in 2022 included establishing the German Agency for Transfer and Innovation (**DATI**) and **updating the Strategy for the Future of Research and Innovation**. The executive board of the Fraunhofer-Gesellschaft was involved in the stakeholder discussions on DATI and in the Strategy for the Future of Research and Innovation. As such, important innovation and science policy concerns for Fraunhofer were incorporated into the political process. The amendment of the Act on Fixed-Term Employment Contracts in Science (Wissenschaftszeitvertragsgesetz — WissZeitVG), which is planned for 2023, is being monitored by Elisabeth Ewen, Head of Human Resources, Corporate Culture and Legal Affairs.

Russia's war of aggression against Ukraine, which violated international law, led to **geopolitical upheaval** that necessitates new approaches to energy and defense policy. Managing the energy crisis and achieving independence from fossil fuels played a key role in 2022. Using hydrogen as a central energy source for future climate-neutral industrial locations was endorsed politically, economically, and in the view of society as a whole. Fraunhofer contributed to this with numerous initiatives. The energy crisis also posed significant challenges to Fraunhofer in 2022, both financially and organizationally. The advice Fraunhofer gave to policymakers helped agreements to be reached on emergency gas assistance, a gas and electricity price cap and a hardship clause for particularly energy-intensive research for the non-university research institutions.

At the same time, defense and security policy in Germany has undergone a paradigm shift, which can be seen in the support for Ukraine by supplying arms and the special forces of the Bundeswehr. The Fraunhofer-Gesellschaft considers **research and transfer activities** in this area to be essential for **future defense capability** and is committed to permanently strengthening this policy area. In 2023, research funding in the defense and security sector, which has not yet been expanded, remains a major issue.

Fraunhofer expands on individual discussions with selected stakeholders from the legislative and executive branches by running **event formats** that have a broad impact. The parliamentary breakfast format "Fraunhofer Morning Radar" resumed partial on-site meetings, with people attending the premises of the German Bundestag. Fraunhofer experts gave interested members of the German Bundestag their assessments on the topics of construction, cybersecurity, energy and resources, and defense. "Fraunhofer at Lunch" is another format that Fraunhofer established in 2022 for members of the Bundestag and representatives of the federal ministries to discuss subjects such as digital mobility, digital health research and bioeconomy.

International activities

Fraunhofer-Gesellschaft's internationalization strategy aims to create scientific value within its own organization and to generate profitable effects for Germany and Europe, as well as in the respective partner country. Fraunhofer is succeeding in developing sustainable solutions to global challenges by cooperating with the best in the world. 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 (in Sweden)
- Fraunhofer Singapore Research Ltd.

These international affiliates function as the legal entities supporting Fraunhofer research centers outside of Germany, which number 12 at the reporting date. These institutionalized Fraunhofer collaborations with local universities facilitate long-term research activities abroad. As their work is not profit-oriented, the international affiliates generally qualify for base funding from their country of domicile, and they are financed in a manner similar to the Fraunhofer funding model.

With the **Fraunhofer Centre for Applied and Integrated Security (CAIS)**, **Fraunhofer Singapore** repositioned itself in its field in 2022. Alongside its new partner institute Fraunhofer

Institute for Applied and Integrated Security AISEC, this will conduct research into secure communication methods using quantum technology and quantum security. Partners on the Singapore side include Nanyang Technological University (NTU) and the National University of Singapore. The internal PACT program (Program Affiliate Cooperation for Knowledge Transfer) promotes cooperation and technology transfer between the international affiliates and the German Fraunhofer institutes.

As part of the **Fraunhofer Innovation Platforms** (FIPs), Fraunhofer institutes cooperate with a foreign university or a non-university research institution on a certain area. The longer-term cooperation pursues joint applied research, joint projects for customers from industry, and participation in publicly funded projects. Three new FIPs were launched in 2022: In Italy, the **Fraunhofer Innovation Platform for Waste Valorisation and Future Energy Supply at University of Bologna FIP-WE@UNIBO** researches resource and waste management. The platform is a collaborative effort of the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT (institute branch Sulzbach-Rosenberg) and the University of Bologna. The **Fraunhofer Innovation Platform for Sensors and Applied Systems at Tel Aviv University FIPSENS@TAU** was established in Israel. The Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT and Tel Aviv University are cooperating to develop hardware with close links to software, including research on algorithms, data processing and networking through to human-machine interfaces, cognition and ethical aspects. The **Fraunhofer Innovation Platform for Hydrogen Energy at Korea Institute of Energy Technology FIP-H2ENERGY@KENTECH** was established in South Korea. Under the leadership of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS, a Fraunhofer consortium of six institutes is bundling various competencies on hydrogen technologies throughout the entire value chain.

The internal program **ICON (International Cooperation and Networking)** enables cooperation with excellent foreign scientific universities and non-university research institutions in projects that typically last three years. Four new projects were launched in 2022: The Fraunhofer Institute for Software and Systems Engineering ISST is working with Aarhus University Hospital in Denmark on the **Predictive Hospital** project. Data-driven AI-assisted processes are set to pave the way for predictive management of hospitals. Alongside the Carnegie Mellon University (CMU), Pittsburgh, USA, the Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP is conducting research into the further development of key electronic components in the field of wireless, optical and quantum communication through the **New Generation of Key Components for Wireless, Optical and Quantum Communication by Tunable Ferroelectric Nitrides** project. The Fraunhofer Institute for Material and Beam Technology IWS and the Fraunhofer Research Institution for Additive Manufacturing Technologies IAPT, together with the Royal Melbourne Institute of Technology RMIT, Australia, are tapping into the potential of in-situ microstructure manipulation in additive manufacturing (AM) of metals as part of the **UltraGRAIN** project. The Fraunhofer Institutes for Cell Therapy and Immunology IZI and for Manufacturing Engineering and Automation IPA are conducting research with Oslo University Hospital, Norway, in the **DESIGNER NK** project on the production of cell-based drugs for novel cancer therapies, in this case using natural killer cells.

The **Fraunhofer International Mobility Program** (FIM) promotes international mobility and networking by arranging stays abroad for Fraunhofer employees from all areas of the institute. These stays can last several months and encourage the exchange of knowledge. In 2022, 29 stays were approved, with the destinations tending to be the countries where innovation is prevalent in Northern Europe, North America and Australia.

International Fraunhofer representative offices in China, Brazil, India, Japan and Korea function as hubs for networking and marketing. They provide local support for all Fraunhofer institutes in initiating and setting up cooperations with research partners from their respective countries. The representatives provide the Fraunhofer research portfolio with a crucial impetus thanks to their knowledge of the respective regional and local research landscape. In addition, senior advisors with similar responsibilities are active in seven countries across the world.

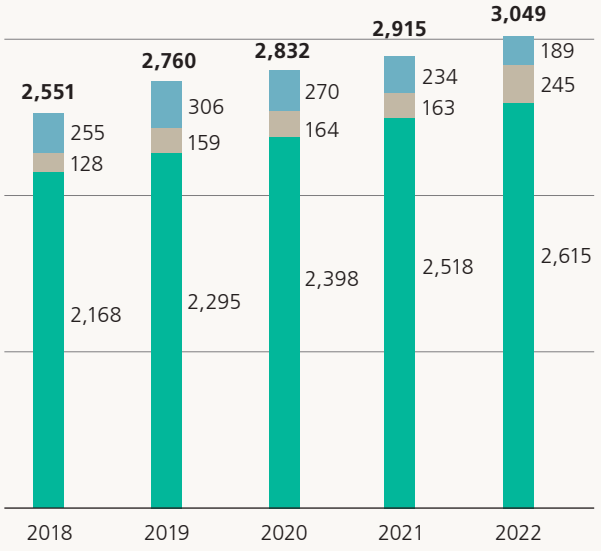
Business report

Total business volume

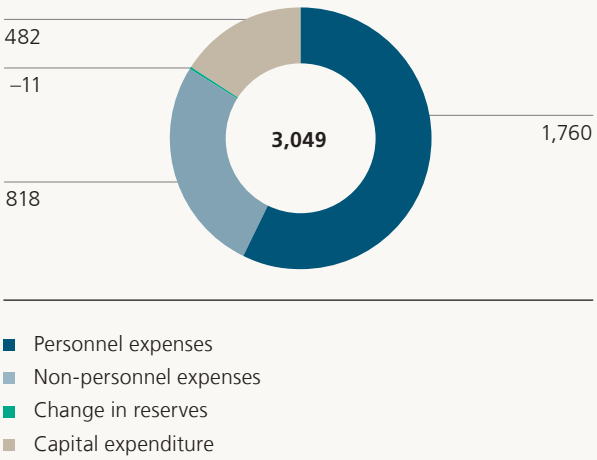
Despite difficult global economic conditions, Fraunhofer can reflect on an economically successful 2022 following two years of crisis caused by COVID-19. In 2022, total business volume grew by 5 percent to around €3.0 billion, reaching the €3 billion threshold for the first time. Contract research accounted for 86 percent of this sum (around €2.6 billion) and represents the organization's core activity. Around one third of contract research funding is provided by base funding from the German 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 €245 million in the reporting period. Major infrastructure capital expenditure amounted to €189 million. These 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 extraordinary item "License-fee revenue reserve for statutory purposes." 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 2022, Fraunhofer's capital expenditure amounted to €482 million overall, a 16 percent share of the total business volume. Personnel expenses increased by 7 percent to €1,760 million. This is primarily due to a 1.8 percent increase to the pay scale that took effect on April 1, 2022, an increase in permanent staff of 3.7 percent, and an increase in personnel provisions of €34 million. At €818 million, non-personnel expenses were 2 percent higher than in the previous year. The reserve was used during 2022 to cover liquidity requirements and €11 million net was released to provide funds to establish performance centers and equip Fraunhofer institutes with photovoltaic systems.

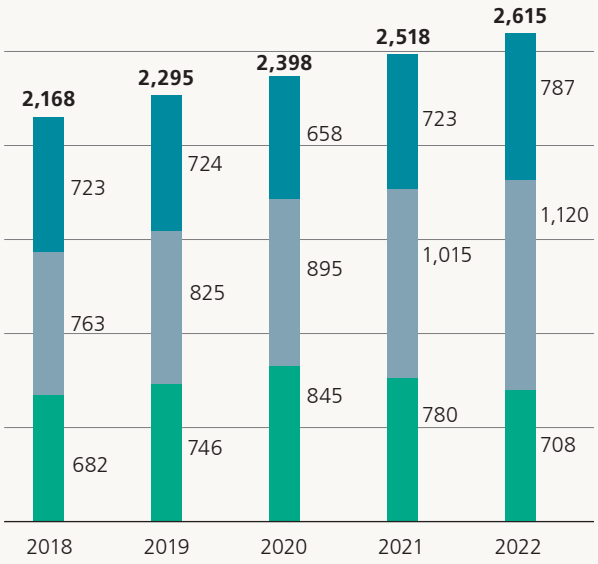
Fraunhofer total business volume in € million



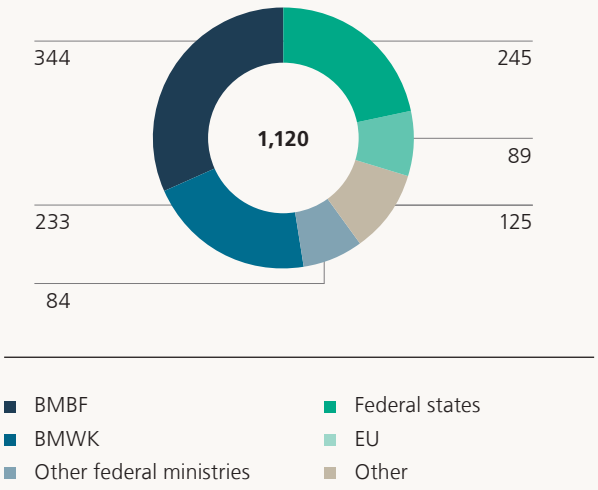
2022: Total business volume by budget in € million



Revenue from contract research in € million



2022: Revenue from publicly-funded projects in € million



Contract research

Contract research is the mainstay of Fraunhofer's business activities and, in line with the **Fraunhofer funding model,** consists of three core areas, each contributing equal amounts to the organization's finances:

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

In 2022, the base funding requirement decreased by 9 percent to €708 million. Base funding is provided by the German Federal Ministry of Education and Research (BMBF) and the state governments at a ratio of 90:10. **Industrial revenue** recorded growth of 9 percent to €787 million, exceeding the previous high achieved just before the COVID-19 pandemic in 2019. License-fee revenue from industry increased particularly significantly by 40 percent to €160 million due to the purchase of a larger patent portfolio. Revenue from contracts with industry increased by 3 percent to €627 million.

Revenue from publicly-funded projects increased significantly again in 2022. Project funding from the German federal government, in particular, jumped by 19 percent to €661 million. Within this, the revenue of the German Federal Ministry of Education and Research (BMBF) increased by 33 percent to €344 million, the funding of the Federal Ministry for Economic Affairs and Climate Action (BMWK) by 4 percent to €233 million and the revenue of the other federal ministries by 18 percent to €84 million. Project funding of the German state governments rose by 4 percent to €245 million. At €89 million, EU revenue was slightly below the previous year's level. Other revenue decreased by 5 percent to €125 million and includes revenue from foundations, universities, other research funding institutions, and license-fee revenue of €1 million from other customers outside industry.

In addition to being one of the Fraunhofer institutes' criteria for success, the high **share of funding** coming from external project revenue is a unique selling point for the Fraunhofer-Gesellschaft. The project funding share therefore serves both as a key performance indicator and as a barometer for establishing an optimal funding mix in contract research. It is calculated as the share of project revenue in the operating budget, including imputed depreciation of capital assets (excluding initial funding for newly established research institutions and excluding changes in reserves). After a slump in 2020 caused by COVID-19, the project funding share increased again to 73.3 percent in 2022. Due to the sharp increase in project funding from the German federal government, the funding share from the German federal government and German state governments rose significantly to 34.8 percent. The share of industrial revenue also increased to 30.4 percent.

Additional research funding

Additional research funding covers long-term research activities that fall outside the scope of regular base funding. In addition to 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 Computer Graphics Research IGD in collaboration with Technical University of Darmstadt and Darmstadt University of Applied Sciences. Its research focuses on the protection of critical infrastructures such as power and transportation, and the safeguarding of IT systems. The center applies an interdisciplinary approach, combining IT and engineering with legal and economic issues, psychology and ethics. ATHENE is funded by the BMBF and the state of Hessen in a ratio of 70:30 and recorded a budget of €21 million in 2022.

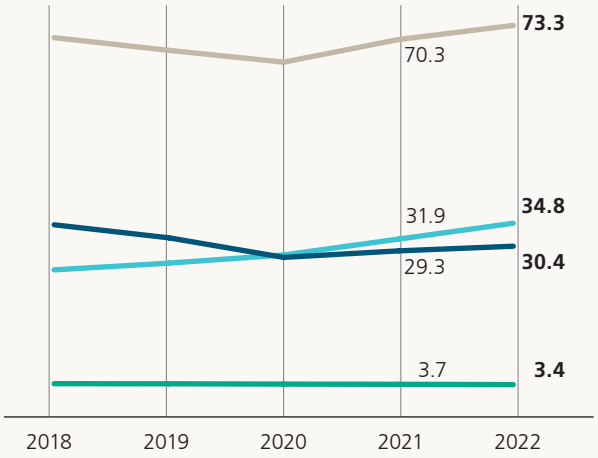
With expenses of €82 million, the development of the **Research Fab Battery Cells FFB** continued to gain momentum in 2022. The BMBF is providing a total of €500 million in funding for this large-scale initiative through project finance. The state of North Rhine-Westphalia is providing an additional €200 million for the construction of a building to house the new facility in Münster. The Research Fab Battery Cells FFB is to become the center for developing modern and scalable battery cell production for Germany and Europe.

In the field of **defense research**, Fraunhofer has pooled the research and development (R&D) activities of seven institutes that 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 resulting from natural disasters or military, technological, terrorist or criminal activity. Defense research grew by 7 percent to €142 million in 2022, mainly due to an increase of €8 million to €83 million in base funding from the BMVg. Project funding from the BMVg increased by €1 million to €59 million.

Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises building projects and the purchase of scientific instruments and furniture to equip new facilities. At €189 million in 2022, investments in **construction and equipping of new facilities** was below the previous year's level. The amount spent on building projects decreased by €20 million to €152 million, of which €117 million related to major and €35 million to minor building projects. Investments in equipping of new facilities decreased

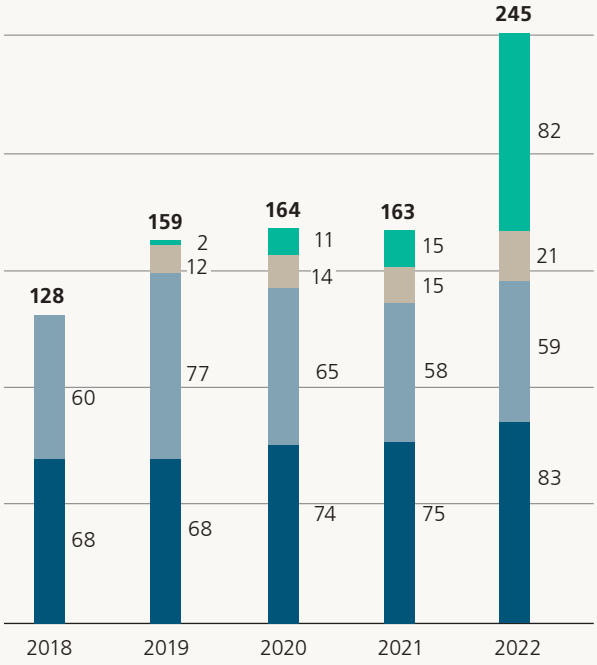
Funding share in %



- Total project revenue*
- Industry
- Federal and state governments
- EU

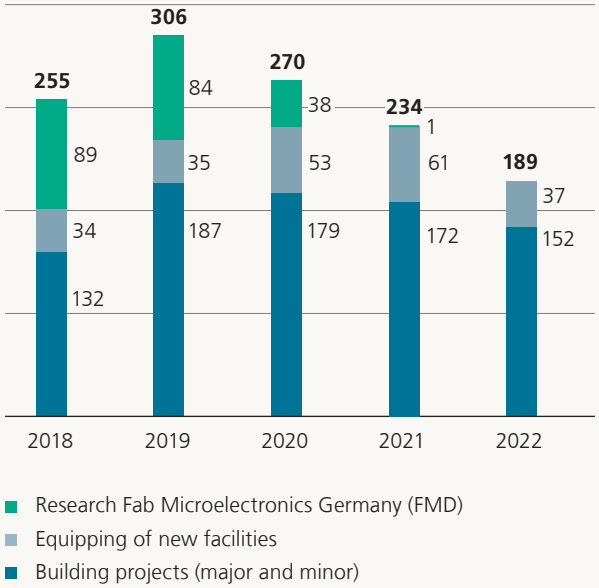
* Funding share from other revenue in 2022: 4.7%.

Additional research funding in € million



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

Major infrastructure capital expenditure in € million



by €24 million to €37 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 funding required from federal and state governments by an equivalent amount. Minor building projects are financed from joint base funding in a ratio of 90:10. The funding required from the German federal and state governments totaled €158 million. ERDF funds from the German state governments and other revenue accounted for €31 million of project revenue.

The **Research Fab Microelectronics Germany (FMD)** is in regular operation and did not cause any further investment in 2022. The German Federal Ministry of Education and Research (BMBF) has provided funding for the set-up of the FMD through project finance since 2017, thus bolstering a key German industry by means of microelectronics research.

Financial and net asset position

At December 31, 2022, the Fraunhofer-Gesellschaft had total assets of €4,617 million, up €431 million or 10 percent when compared to the previous year. Assets presented in the ordinary accounts comprised 99.7 percent of total assets, with non-profit organization capital accounting for the remaining 0.3 percent.

Noncurrent assets accounted for 60 percent of assets and were €136 million higher at €2,782 million. This increase was chiefly attributable to the fact that capital expenditure on property, plant and equipment exceeded depreciation of those assets. Property, plant and equipment grew by €143 million to €2,724 million.

Current assets accounted for 39 percent of assets and were €327 million higher at €1,805 million. Within this, receivables from the German federal government and the German state governments from project billing (including contracts) increased by €83 million to €335 million. Receivables from affiliated companies remained at the previous year's level of €8 million. Cash and cash equivalents (including bank account balances) increased by €61 million to €293 million. The value of the securities portfolio was €72 million higher, at €512 million. Of this, €404 million stemmed from license-fee revenue reserve, €21 million corresponded to the extraordinary item "For financing restructuring measures" and €87 million was from a patent sale.

Equity — which comprises the non-profit organization capital that is not financed by government grants (€15.5 million) and the reserve for statutory purposes (€15,725) — increased by a marginal amount. Economic equity also includes four kinds of extraordinary items recognized in the balance sheet. The extraordinary item "Grants relating to noncurrent assets" was €137 million higher at €2,771 million. The extraordinary item "License-fee revenue reserve for statutory purposes" decreased by €11 million to €404 million. The "Extraordinary item for payments from patent sales" was €128 million. This item is matched by other receivables and securities of an equivalent amount on the assets side of the balance sheet.

An extraordinary item of €21 million was entered for the necessary restructuring of cleanroom infrastructure. This item 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 collaboration and the quality of services. A sum of €46,000 was allocated to the item, while reversals amounted to €3,512,300.

The extraordinary item "Grants used to finance current assets" is not included in financial 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 funding and amounted to €380 million at the reporting date.

Provisions increased by €33 million to €243 million, €53 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 the German federal and state governments totaling €107 million was entered on the assets side of the balance sheet.

Liabilities rose by €109 million to €650 million. In addition to an increase of €63 million in unappropriated grants from federal and state governments from base funding and project billing, trade payables and other liabilities also rose by a total of €45 million.

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. The Fraunhofer funding model stood up to the test in times of crisis and is built on a solid foundation.

Shareholdings and spin-offs

At the reporting date, the Fraunhofer-Gesellschaft held equity investments in a total of **82 companies** operating in a diverse range of sectors. The transfer of technology to industry formed the focus of activities at 58 of the companies in the investment portfolio, while a further 18 equity investments were of a strategic nature. Equity investments also include six affiliated companies. In 2022, the Fraunhofer-Gesellschaft invested a total of €0.6 million in the acquisition of equity interests in shareholdings. The Fraunhofer-Gesellschaft added four companies to its investment portfolio and divested its shares in six. The total carrying amount of shareholdings (including shares in affiliated companies) decreased to €9.2 million (2021: €10.4 million). Income from the divestiture of shareholdings came to €11.1 million.

Spin-offs are an integral part of Fraunhofer's strategy for exploiting its industrial property rights. The Fraunhofer Venture department generally supports spin-off founders as they prepare to launch their new business. In individual cases, Fraunhofer takes a minority share in the spin-off under company law as part of its technology transfer activities. In 2022, Fraunhofer Venture provided support to 49 new spin-off projects; in total, 18 new spin-offs were established from the Fraunhofer-Gesellschaft. Fraunhofer has set itself the goal of increasing not only the number of spin-offs but also their proportional contribution to overall industrial revenue. The innovation hub AHEAD offers a comprehensive package of targeted measures and programs to help achieve this objective.

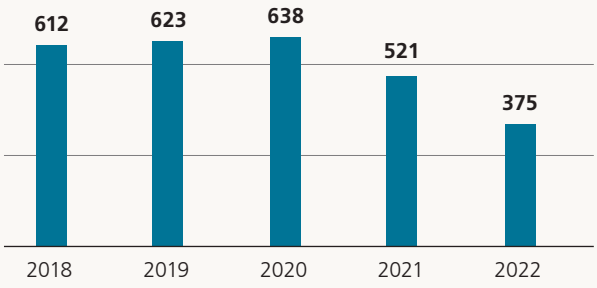
Exploitation of intellectual property rights

The Fraunhofer-Gesellschaft remains the **leader** among German research institutions in terms of its annual number of invention disclosures and new patent applications. However, the corresponding figures are lower than in previous years. In 2022, 443 invention disclosures were submitted by the Fraunhofer institutes. By contrast, there were between 700 and 800 inventions annually in previous years, with a total of 604 in 2021. One reason for this decline is the reduced on-site presence of staff at the institutes due to the COVID-19 pandemic. In line with the decline in invention disclosures, the number of patent applications claiming rights of priority has also fallen. In 2022, 375 patent applications claiming rights of priority were filed with the relevant patent offices.

The Fraunhofer portfolio of active patent families, each of which comprises all intellectual property rights in different countries, remained close to the previous year's figure at 7,414. Despite the temporary decline in the number of invention disclosures, the general strategy of the Fraunhofer institutes remains to secure valuable inventions permanently under patent law. To guarantee ongoing exploitation of intellectual property rights, Fraunhofer is continuing its efforts to group patents owned by different institutes into portfolios that are then offered to selected companies, licensed or, in some cases, sold.

As a rule, Fraunhofer generates revenue from the **commercial exploitation of intellectual property** (IP) rights by way of license fees. In addition, IP can also be contributed to patent pools or exploited through the sale of IP. The most successful of these pools consist of patents for audio and video encoding. In conjunction with other parties from different countries that hold patents that are relevant to standards, Fraunhofer uses various patent pools to issue licenses on a worldwide basis. The income from these pools is reinvested in pre-competitive research, thus helping strengthen Germany's position as a research hub for the long term. In 2022, Fraunhofer concluded 301 new IP licensing or sale agreements, bringing the total number of active agreements at the end of 2022 to 3,141. Revenue from the licensing and sale of IP amounted to €161 million and thus increased noticeably compared to the previous year due to an extraordinary effect arising from the sale of a larger patent portfolio. Of this, €160 million of the license-fee revenue came from industry and €1 million from other customers outside industry.

Patent applications claiming rights of priority



Corporate social responsibility issues

Responsibilities of the Fraunhofer-Gesellschaft

Corporate social responsibility (CSR), i.e. the accepted responsibility of contributing to sustainable development, affects almost all of Fraunhofer's business and organizational units. The need to establish holistic coordination across all three sustainability dimensions became apparent with increasing demands from society, politics and business, as well as Fraunhofer's own requirements for quality, future viability and contributions to sustainable development. The aim is for CSR or sustainability to become an inherent aspect of comprehensive overall management. This requires sustainability criteria and goals to be incorporated into the overall Fraunhofer strategy. There are five areas of responsibility for CSR fields of action: organizational management, research and development, resources and procurement, employees, and social commitment. The topics include operational aspects such as sustainable resource consumption, responsible HR management, as well as research activities and how they contribute to solving societal challenges. The structure required for this was defined and implemented in 2022. As a result, specific responsibilities and CSR issues were established in all executive board units. This new approach means all board members of the Fraunhofer-Gesellschaft assume these responsibilities, committing themselves to sustainable development in general and to the areas assigned to their executive board unit.

Since 2014, the Fraunhofer-Gesellschaft has regularly reported on the impact of its work on the environment and society, as well as on the associated opportunities and risks (CSR). The corresponding targets, measures and key figures were communicated in sustainability and CSR reports in 2014, 2016 and 2019, and a new report was published in 2023. The executive board also established a CSR task force to more firmly consolidate the complex social responsibility requirements in Fraunhofer's overall structure and work practices. For example, recently, the implementation of the German Supply Chain Due Diligence Act (Lieferkettensorgfaltspflichtengesetz, LkSG) was coordinated effectively and efficiently within this new structure.

As an internationally active research institution, Fraunhofer is committed to gaining knowledge through the free exchange of ideas across borders. Liberal democratic constitutional order is required to enable us to exchange points of view and arguments, and thus create knowledge. In light of current events in Ukraine and the resulting political developments, the Fraunhofer executive board, in line with other members of the Alliance of Science Organisations in Germany, has decided to freeze all ongoing projects and interaction with Russia and Belarus for the time being. Scientific thought and cooperation do not adhere to national borders. People seeking refuge are supported at Fraunhofer under the given framework. In cooperation with the Alexander von Humboldt Foundation, refugees are given access to employment opportunities at Fraunhofer.

Realignment of the compliance management system

The Fraunhofer-Gesellschaft believes that good corporate governance means not only complying with legal requirements as a matter of course, but also ensuring values such as trust, respect and fairness are maintained, both internally and externally. Fraunhofer has been operating a compliance management system (CMS) since 2010. It was successfully assessed and confirmed in the 2015/16 audit and has been continually developed since then in order to comply with increased regulations in the field of research. In light of increasingly complex legal requirements and the resulting need for stronger links between the legal department (2C) and the compliance management function, the compliance office and its tasks were reorganized in 2022. The compliance management function was delegated to 2C by the chief compliance officer and is performed through the CMS. Topics such as the central management of compliance risks in the matrix organization, more efficient guideline management and the further development of the Internal Control System (ICS) are being further expanded, which helps make the CMS more effective. Professional

consultants support this process as needed in terms of further development, in accordance with the auditing standard IDW PS 980 (n.F.). This means that Fraunhofer can prevent violations of external and internal regulations even more effectively with an evaluated, effective CMS.

At Fraunhofer, we think of compliance as a business enabler, whereby the employees of the central compliance department are reliable points of contact who know the business processes and can generate added value. We believe that acting in compliance means weighing up coherent measures in the spirit of fair cooperation within jointly defined guidelines for responsible and successful research. The compliance framework ensures, among other things, that control processes are coordinated by having various participants with autonomous responsibilities and functions interact within the CMS. All employees taking part in the defined processes carry out permanent checks (e.g. dual control principle). As part of the ICS, topic owners in the specialist departments or institute management/heads of administration regularly review regulatory and procedural requirements (e.g. compliance with inspections). The central compliance department is responsible for reviewing the effectiveness of the CMS based on risk prioritization and for further developing the elements based on this. Risk management and the legal departments are important interfaces in this regard. Internal Auditing reviews ensure the provision of an independent, objective and holistic assessment of Fraunhofer's ICS (internal audit), thus leveraging its safeguarding function vis-à-vis committees and the executive board as a further line of defense.

In addition, the innovative and flexible business model of modern science and applied research with social responsibility requires compliance to be integrated into the corporate culture. The rules, roles and values must be communicated to all employees and exemplified by their managers. This requires orchestrated interplay between cross-divisional competencies from HR, communications, legal affairs and compliance, among others. By combining personal responsibility with knowledge of the guiding principles and the rules and regulations, we can ensure that our employees and managers act in a responsible and compliant manner on behalf of Fraunhofer. This is the only way to ensure that Fraunhofer can continue to be successful in the long term, leaving enough room for our important tasks: research and the transfer of innovation.

Sustainability research

As Europe's largest applied research organization, Fraunhofer pursues a special social mission with great leverage. The Fraunhofer guiding principles state: "Through our research we contribute to the sustainable development of an ecologically sound environment, and an economically successful and socially balanced world. We are strongly committed to this responsibility." Fraunhofer makes positive contributions to the economy, the environment and society with research solutions such as new or improved processes, new materials and new technologies.

The Council of Experts on Climate Issues, initiated by the German federal government in 2020, is chaired by Prof. Hans-Martin Henning. Henning is one of the two directors of the Fraunhofer Institute for Solar Energy Systems ISE and spokesperson for the Fraunhofer Energy Alliance. The tasks of the Council of Experts on Climate Issues regulated by the German Climate Change Act include reviewing the Federal Environment Agency's estimates of greenhouse gas emissions and the assumptions on the greenhouse gas-reducing effect of emergency measures and climate protection programs.

Fraunhofer also fulfils its sustainable research responsibilities through the **Fraunhofer lighthouse** projects, which are the beacons of internal research funding. For example, "SUBI²MA — Sustainable Biobased and Biohybrid Materials," which started in early 2022, focuses on developing novel materials with improved degradability and previously unattainable functionalities. These include complex sensors, and use as a molecular filter or as a biocatalyst. Such materials help the chemical and plastics industries to (largely) dispense with fossil raw materials and provide new high-tech materials to their customers from the automotive or textile industries, and the health or construction sectors, for example. Digitally transforming the development process should also shorten the time to application maturity in the future. Sustainability is also clearly in the foreground of the lighthouse projects funded from 2023 onwards. For example, the "Bau-DNS" project focuses on a comprehensive process for sustainable, modular and circular building refurbishment. The current crises mark a turning point for commercial, security and sustainability policies. The current bidding round under the heading "Times of change" and with funding starting in 2024 is all about these changes.

To the Fraunhofer lighthouse projects

In European politics, Fraunhofer is taking up a position in relevant committees and projects to drive forward the green and digital transformation. Participating in European initiatives such as Hydrogen Europe Research (HER), the Bio-based Industries Consortium (BIC), European Energy Research Alliance (EERA) and European Solar PV Industry Alliance (ESIA) contributes to shaping the European research and innovation agenda of the **European Green Deal** and **REPowerEU**. In addition to participating in a consultation on the European Partnership for Sustainable Food Systems, Fraunhofer researchers are contributing to the **Sustainable Food Consumption** expert group of the EU Commission's Scientific Advice Mechanism on reviewing the Farm-to-Fork Strategy.

In the energy sector, the InnoPush project "EnDaSpace PLATON — Platform Economy in the Application Context of Hydrogen" was partially transferred to EU level. In the "ENERSHARE" project funded by Horizon Europe, three institutes have been working as part of an international consortium on the **creation of a European energy data space** since 2022. After taking part in a consultation on the digital transformation of the energy system, Fraunhofer employees built on this by being invited to expert discussions with the EU Commission in 2022. This process gave rise to the EU Commission's action plan on the digital transformation of the energy sector. Fraunhofer was also involved in the legislative process to amend the Renewable Energy Directive. The Fraunhofer thesis study "Digital transformation of the energy system" was published at EU level.

The **Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation)** also runs a funding program aligned with the UN's Sustainable Development Goals (SDGs). With an annual funding volume of €5 million, it provides targeted support for projects by Fraunhofer researchers that help to make the world more environmentally friendly, socially equitable and financially sustainable. The following projects are examples from 2022: "WiBACK — Connecting the Unconnected" and "PreCare — Medical Care for Remote Areas in Africa." The foundation is focusing increasingly on collaborative activities with civil society to facilitate the transfer of project results and is promoting collaboration between civil society, science and industry. Plans are in place to bolster dialog with citizens through participative events and schemes in the future.

Socially responsible research

Socially responsible research describes a research process that contributes to sustainable development on the basis of critical and systematic reflection on research issues, theoretical assumptions, methods, results and their communication and effects.

In 2016, the output of the "Socially Responsible Research" project, which is funded by the German Federal Ministry of Education and Research (BMBF) and implemented under the leadership of Fraunhofer, was a framework for reflection on ethical and socially relevant aspects of projects in the field of research and development (R&D). In 2022, a follow-up project was launched internally at Fraunhofer as a result of this. The aim of this project was to directly implement the recommendations made at that time in all Fraunhofer R&D projects and to support project participants in practice. One of the criteria developed at that time is, for example, reflection on the effects of the project results, i.e. their impact assessment and risk assessment. This is already rooted in an updated Fraunhofer internal regulation on good scientific practice. In addition, scientists are made more aware of such (new) ethical issues and empowered accordingly. Other criteria are already components of quality-assured project management. Even greater consideration must be given to cooperation with scientific partners from other disciplines to achieve the project goal (interdisciplinarity) or integration, if necessary, of later users into the project (transdisciplinarity), for example. The aim of this new internal project is to further increase the excellence of Fraunhofer projects with the support offered to project teams (guidelines, workshops, online tools).

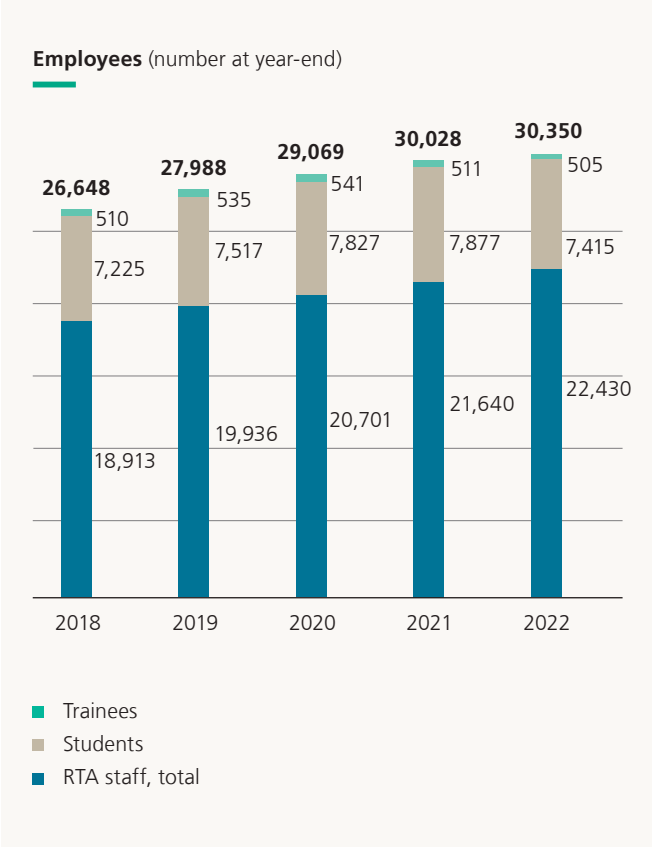
An important way to make innovations relevant, helpful and social is through social negotiation processes, transparency, dialogue and participation. Participatory research and innovation processes complement the focus on economic needs in Fraunhofer research. As part of the current EU project "FRANCIS — Frugal Innovation by Citizens for Citizens," citizens are actively involved in research and innovation processes. To this end, the Fraunhofer Institute for Industrial Engineering IAO and the Fraunhofer Information Center for Planning and Building IRB are initiating Open Innovation Challenges together with other partners. Interested users from marginalized population groups such as the socially deprived or elderly are called upon to develop ideas for high-quality, simple and low-cost (in short, frugal) innovations and put these into practice together with industrial partners (funding period: 2021–2024).

Employees

At year-end 2022, Fraunhofer had 30,350 employees, 22,430 of whom were research, technical or administrative staff (RTA staff), 7,415 students, and 505 trainees.

On its way to creating a flexible, cooperative, customer-oriented working and research environment for self-determined employees, Fraunhofer can look back on a positive year at the end of 2022. The "New Work@Fraunhofer" initiative delivers strategically important value in terms of future viability: This concerns, in particular, the organization's innovative strength, employer attractiveness and resilience. Between 2020 and 2022, around 45 institutes embedded New Work in their organization through ten series of modules (INITIATE, SYSTEMATIZE and DEVELOP). Different priorities have been set in the institutes: from creating the conditions for time- and location-flexible working to introducing agile working methods and designing new room layouts adapted to new work routines. A total of around 15,000 employees are now directly or indirectly involved in New Work activities.

The Fraunhofer-Gesellschaft's overarching mission of "**Transfer via individuals**" also continues to manifest itself in the "Careers with Fraunhofer" approach, which is based on a comprehensive HR development strategy aimed at supporting



employees' individual career planning. The key tool for this planning is and remains the annual employee meeting, which is implemented as a development meeting at Fraunhofer. Individual development planning focuses on Fraunhofer development and career paths (both internally and with regard to traditional follow-up careers in business, science or self-employment). These are consolidated through defined qualification fields, topics and measures.

The widespread introduction of the **SAP tool SuccessFactors Talent** means that a uniform platform offering comprehensive, digital support for development planning is now available throughout Fraunhofer. Therefore, development planning is clearly criteria-based and comprehensible, while the electronic workflow ensures the individual process steps are implemented. At the same time, the SAP Learning Management System was introduced as a uniform learning platform that consolidates the learning opportunities for Fraunhofer employees and makes them easily accessible. In addition, target group-specific **career programs** promote networking across the institutes: Vintage Class and Advanced Management Class for top and senior management, TALENTA for female researchers and female scientific managers and Step Forward for young professionals. A new development program designed as part of the implementation of the "Code of Conduct for Conduct — Doctoral at Fraunhofer" is available to supervisors of employees working on doctorates.

The systematic **exit survey** of employees leaving the company is an important instrument for monitoring the effectiveness of the measures within the overall HR development strategy. The important question of whether employees leaving the company would recommend Fraunhofer as an employer revealed a positive trend in 2022: Approval ratings are currently at 70 percent (2021: 60 percent and 2020: 59 percent). There was also positive development in the crucial question regarding the Fraunhofer approach of "Transfer via individuals": In 2022, 62 percent of those who had left Fraunhofer of their own accord said that their planned development goals had been met and that the next step in their professional development was imminent.

These working conditions are one of the reasons that Fraunhofer is ranked in the Top Employers list every year. In 2022, the Fraunhofer-Gesellschaft was also one of the most popular employers in the Glassdoor employer ranking and came second in the research category in the Trendence barometer of students in engineering and computer science, and of young professionals. The Fraunhofer-Gesellschaft was also accredited with the "HR Excellence in Research" seal once again.

Diversity

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.

In order to achieve the long-term corporate goal of equal professional opportunities for women and men, we have implemented an overall strategy since 2013, which consists of six systematically interlinked fields of action: recruitment, career progression, communication, cultural transformation, monitoring and general conditions. Target group-specific measures were developed in each of these six fields of action. These measures are regularly developed further and expanded, while also being subject to regular internal evaluations, surveys and consideration of current external studies.

In 2022, the **equal opportunities support program** was continued in order to support institutes in the implementation of equitable structures. In the period from 2021 to March 2023, a total of 45 institutes, as well as the Fraunhofer headquarters, were able to use the latest ideas from thematic workshops and exchanges on best practices and networking in peer groups to advance equal opportunities at the institute. The participating institutes have reported key added value, such as hiring more female scientists, further development of on-site recruitment processes and implementation of new measures by management groups that have recently been established. **TALENTA** is a targeted and holistic support and development

program that has been a central pillar for the promotion of more equal opportunities in research and leadership at Fraunhofer since 2013. In this time, over 724 female researchers at Fraunhofer have been able to take advantage of the comprehensive support for career and research time, as well as qualification and networking formats, to achieve their career goals (e.g. completing their doctorate, further developing their leadership skills or strengthening their scientific visibility). The program is subject to regular evaluation and adjustment. In 2022, 72 female scientists received support.

At the end of 2022, the share of employees with severe disabilities was 2.4 percent (2021: 2.6 percent). The Fraunhofer-Gesellschaft has set itself the goal of expanding its commitment to promoting **inclusion** and making an extra effort to attract, develop and retain people with disabilities. The Corporate Culture — Diversity department has also been developing an overall strategy since 2022.

Equal opportunity principles form the foundation of the innovative strength of the Fraunhofer-Gesellschaft and represent an essential component of our entire organizational culture. Fraunhofer therefore welcomes and supports the EU Commission's promotion of equal opportunities in research and innovation. For example, Fraunhofer's **Gender Equality Plan** has been introduced as a new funding criterion for research organizations participating in the Horizon Europe program since 2022 and is updated annually. In 2022, Fraunhofer, together with the Max Planck Society and other partner organizations, developed the joint **Inclusion Initiative**. The main aim of this initiative is to set an example for inclusion in the field of research on the International Day of Disabled Persons 2023 and to improve the visibility of commitment to inclusion.

The Fraunhofer-Gesellschaft considers **unconscious bias** to be key for shaping a culture of equal opportunities and diversity. Our overall strategy for reflecting, being more aware of our actions and reducing unconscious bias aims to make employees and managers more aware of the effect of unconscious bias by training them to deal with it and reducing its negative effects. In order to make employees more aware of unconscious bias, the e-learning program "Fairer decisions in everyday research — a digital training module on dealing with unconscious bias more consciously" was developed and made available to all institutes in 2022. The measures and tools include a fun exercise on personnel selection, for example.

The **Diversity Funding Program** was established 11 years ago in order to support institutes in the implementation of new measures to support equal opportunities and diversity. In addition to financial support for work-life-balance projects, there is also funding for institute projects that promote equal opportunities for women and men, that include employees with disabilities and, since 2019, that promote intercultural cooperation. Since the start of the program, a total of 215 applications from institutes have been funded at a total cost of €2 million.

In 2021, the Fraunhofer-wide framework agreement with **pme Familienservice** covering services in emergency childcare, home care and elder care as well as life coaching was extended for a further two years. Since then, the use of the pme Akademie, which includes webinars, e-learning programs and tips for living mindfully, has also been included. In 2022, in addition to 13 cases where childcare was used and 50 requests for home- and eldercare, life coaching was used most frequently, with 122 requests. The range of services offered was expanded as an extraordinary measure to include various forms of assistance in response to the war in Ukraine. This was designed to support employees and their relatives who had been affected by the war. For example, since the start of the war, those affected have been able to access a 24-hour hotline, counselling in English, Ukrainian and Russian, and crisis intervention for support with any concerns and fears they may have. The re-certification of the Fraunhofer **family logo** was postponed to 2023 because of the COVID-19 pandemic. Since 2019, a total of 20 institutes have obtained the Family Logo.

In the Fraunhofer-specific cascade model, Fraunhofer set transparent goals for increasing the proportion of female scientists at the various organizational levels by 2025. At level 3 (scientific employees without management responsibilities), the target for the year was marginally missed with the proportion of women reaching 25 percent (target: 25.1 percent). The target at level 2 was reached once again in 2022 with the proportion of female researchers at 17.8 percent. In contrast, the target of having 15 percent of top management positions held by women was missed by two percentage points, despite all efforts. Since 2020, Fraunhofer has been working with a sourcing team to attract more women to the institute management level. Since then, the sourcing team has identified over 1,600 interested candidates domestically and internationally and has contacted over 780 of them. Out of 12 completed appointments handled by the sourcing team, nine vacancies went to actively approached female candidates, two were filled by men, and one appointment was cancelled. The sourcing team has also been assisting increasingly with the search for potential female candidates for expert reports, audits, appointment committees, conferences and advisory boards for some time now. Fraunhofer is also striving to increase the **proportion of women on the advisory boards** at the institutes by four percentage points each year. The measures adopted by the Research Coordination department and the efforts being made by the institute are having an impact: The target for 2022 was achieved, with the proportion of women on the institutes' advisory boards reaching 31.9 percent (2021: 26.5 percent).

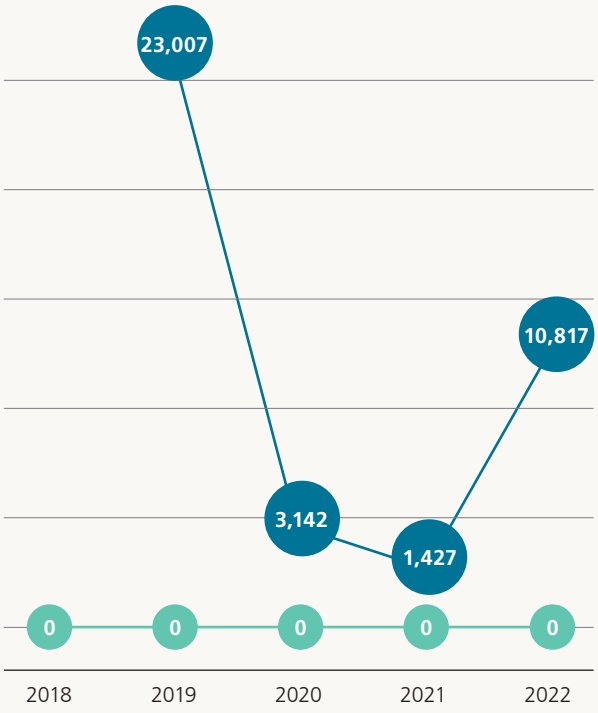
Sustainability in the scientific enterprise

In 2021, Fraunhofer set itself the target of making its scientific enterprise climate neutral from 2030 onwards, if possible. A key element for this is the development of implementation competencies within the organization. As such, the new "Climate Management" department at Fraunhofer headquarters has been coordinating the planned measures since April 2022. All Fraunhofer institutes appointed officers for climate neutrality and sustainability. Implementation of measures has also begun: Among other things, a pilot project for the widespread introduction of energy management systems (EMS) in accordance with ISO 50001 was initiated across six institutes. Thanks to the internal photovoltaic program, 43 plants with a total capacity of almost nine megawatts peak (MWp) are in the planning stage or under construction, or in some cases already completed, as of the end of 2022. The decision to procure green power was realized with the new framework agreement signed in 2023, despite the turbulent developments on the energy markets and rising electricity prices. The institutes explored and, where possible, implemented directly all possibilities for saving energy in the short term in order to help society as a whole in dealing with the energy crisis in the wake of the Russian war against Ukraine and to ensure the continuation of scientific operations.

As the COVID-19 pandemic subsided in 2022, in-person events and face-to-face meetings could take place again. This is clearly reflected in the increase in business trips. Rail travel more than quadrupled compared to 2021 with over 18 million passenger kilometers (PkM) travelled. By using the framework agreement between the German federal government and German Rail (Deutsche Bahn), train journeys for Fraunhofer continue to be regarded as carbon-neutral. Air travel also noticeably increased. At 10,817 tons of CO_2, emissions increased more than sevenfold on the previous year.* Therefore, one important task must be to continue to move over to rail travel and avoid air travel wherever possible. Once again, during 2022, atmosfair projects neutralized the emissions from flights taken in 2021, and flights taken in 2022 are also planned to be offset.

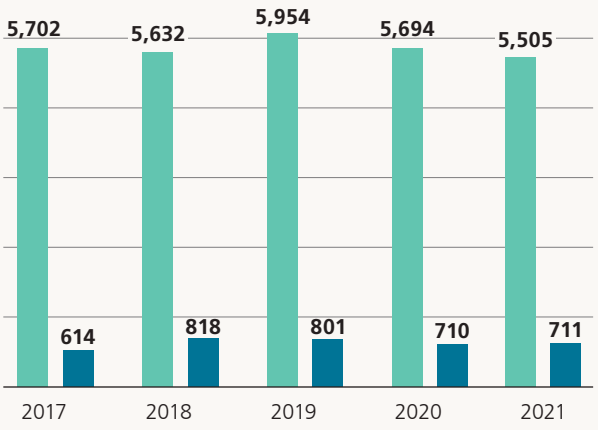
Officers for operational **waste management** and associated documentation were appointed at the Fraunhofer institutes. Up-to-date total waste figures are available for 2021 only. According to these figures, the Fraunhofer institutes generated 5,505 metric tons of non-hazardous waste and 711 metric tons of hazardous waste in 2021. This means there was a slight decrease in non-hazardous waste of four percent but a similar amount of hazardous waste compared to the previous year. The reduction in non-hazardous waste is a result of the efforts made at the individual institutes. The fluctuations in hazardous waste can largely be explained by research project parameters. Most waste generated by projects cannot be controlled directly.

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



- Flight emissions calculated according to the VDR standard + RFI 2.7 (recorded from 2019)
- Rail travel: carbon-neutral due to inclusion in the framework agreement between the federal government and German Rail (Deutsche Bahn), according to the information given by Deutsche Bahn

Volume of waste produced by Fraunhofer institutes, in metric tons



- Non-hazardous waste
- Hazardous waste

* Since the decision to offset air travel in 2019, flight-related emissions have been calculated using the VDR standard with a Radiative Forcing Index (RFI) of 2.7 in order to take into account the total climate impact of flights taken by Fraunhofer employees. In the interests of transparency, these are reported accordingly. In previous reports, the lower values of CO_2 emissions were presented according to GRI/GHG.

Risks and outlook

Risk management and risks

The overall assessment of the Fraunhofer-Gesellschaft's risk situation deteriorated slightly compared with the previous year. In this regard, the assessments show the first effects of the multiple crises, especially the energy crisis and the sharp rise in inflation, but also the challenges arising from the migration to the new SAP ERP system. These do not pose a lasting threat to the Fraunhofer-Gesellschaft.

Fraunhofer takes **risk** to mean all internal and external events and developments that might jeopardize the organization's success. These include both risks where the monetary value can be directly ascertained and qualitative risks. Fraunhofer's **risk management system** is designed to identify existing and potential risks at an early stage and to manage them by means of appropriate measures in such way that they either do not materialize at all or do not have consequences that could endanger Fraunhofer's business success or jeopardize its ability to fulfill its mission in accordance with its statute. To achieve this objective, the Fraunhofer-Gesellschaft has set up a risk management system that takes into account its requirements and structure, undergoes continuous improvement, and has been accepted by Fraunhofer-Gesellschaft auditors as being adequate and suitable for this purpose. In the cyclic risk management process, risk experts in the central departments carry out systematic, standardized risk assessments on a yearly basis. The individual risks identified in this process and the associated countermeasures are then summarized under the appropriate risk categories and prioritized in an annual risk report that is presented to the executive board, enabling individual risks of a similar nature to be evaluated collectively. Additionally, the central departments inform the executive board of relevant risk-related developments — both routinely and on an ad hoc basis — via the established reporting channels.

The Fraunhofer-specific risk classification model provides a framework for the annual risk assessment, which in turn serves as a basis for the risk report presented to the executive board. The first layer of the model consists of four main areas of risk: business model, financing, resources and business operations. The second layer of the model assigns individual Fraunhofer-specific risk (currently 19) to these four main areas.

Business model risk encompasses types of risk that represent a threat to the continuation and further development of the Fraunhofer business model. This relates to both important external conditions and risks regarding the internal design of the business model. Due to the multiple crises — namely the COVID-19 pandemic, supply chain disruptions, Russia's attack on Ukraine, rising (energy) prices, effects of climate change and shortage of skilled workers — negative effects are still to be expected in certain areas of the research portfolio. In anticipation of this, Fraunhofer continues its ongoing activities in relation to strategic portfolio management.

In the context of **financing risks**, the focus is on containing risks that might compromise Fraunhofer's access to research funding or its solvency. The **Fraunhofer funding model** is based on three financing pillars (base funding, public-sector revenue and industrial revenue), each of which contribute about a third of the financing. Due to the current crisis situation, potential budget cuts by the grant authority or restrictions in budget flexibility may lead to a decrease in public funding, as well as to potential partial revocations. Furthermore, the continuation of industrial revenue is uncertain. This is because of the volatile economic environment and the structural transformation in several industries (e.g. the automotive industry) caused by factors such as resource scarcity, which is due, in turn, to supply chain problems, the energy crisis and inflationary pressure. However, the Fraunhofer-Gesellschaft's financing model has proven to be very robust during previous times of crisis, so the Fraunhofer-Gesellschaft is well-equipped to deal with such challenges.

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

The Fraunhofer-Gesellschaft is faced with various challenges as a result of the war of aggression against Ukraine. A wide range of protective measures, which proved their effectiveness during the COVID-19 pandemic and the 2021 flood disaster, were continued and professionalized in order to be able to maintain operational working capacity without restriction. These measures included the tried and tested Fraunhofer crisis management system. In addition, the Fraunhofer-Gesellschaft continuously works to improve its protection, prevention and crisis management processes, and to link these with each other in order to increase resilience against potential hazards and risks. An **emergency energy supply** task force was implemented to safeguard the energy supply. It pools activities related to energy supply and actively supports the institutes in preparing for possible scenarios of energy shortages and in drawing up corresponding emergency plans. The Fraunhofer-Gesellschaft is also developing strategies and measures to shape its own resilient and sustainable energy supply and thus reduce dependence on volatile market prices and uncertain market supply.

Modern, high-performance IT systems help to streamline business processes in research management. Converting the existing ERP system Sigma to the future-oriented **SAP S/4HANA system** leads not only to opportunities, but also to challenges until the processes are optimally adapted to the special features of a research organization of this size and then implemented. Increasing the efficiency of purchasing processes and ensuring that they are compliant in order to counteract the loss of funds and the impact on ratings remains a priority. Another challenge is the further development of the customized SAP tools for invoicing publicly-funded research projects. The SAP project "Level Up" was implemented throughout Fraunhofer to ensure stability and increase efficiency.

The reputation of the Fraunhofer-Gesellschaft and its brand is one of our most valuable assets and forms the basis for long-term economic success. We believe responsible corporate governance means consistently complying with legal and funding requirements. Good scientific practice is a matter of course for us. We are also guided by values such as trust, respect and fairness, both internally and externally.

We understand that reputational damage caused by the misconduct of some individuals can never be completely ruled out. We have therefore decided to further develop our compliance system with the aim of mitigating potential risks and being able to identify and counter misconduct even more effectively (see p. 19/20 Responsibilities of the Fraunhofer-Gesellschaft, Realignment of the compliance management system).

Negative reactions in the media or from society can damage the reputation of the Fraunhofer-Gesellschaft and its brand. In order to identify such risks as early as possible and minimize their impact, we are focused on continuously developing communication, brand management and dedicated monitoring.

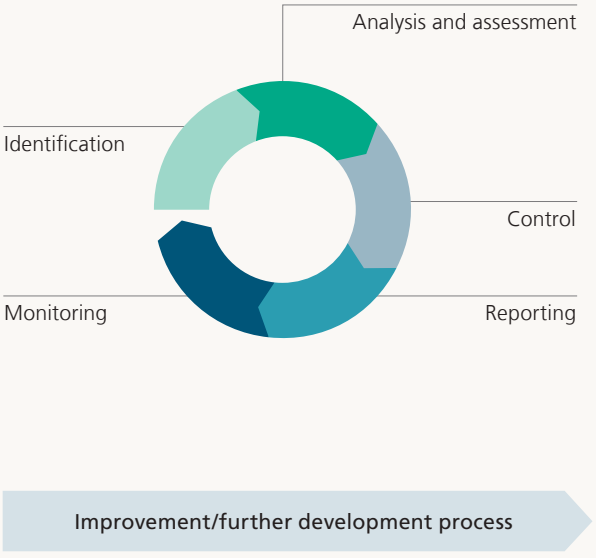
Business operations risk comprises those types of risk that may arise from research and administration processes, or from conducting specific research projects.

The need to establish holistic coordination across all three sustainability dimensions and integrate it in the overall strategy of our organization became apparent with increasing demands from society, policymakers and the economy, as well as Fraunhofer's own requirements for quality, future viability and the contribution to **sustainable development**. In this regard, the previous activities in the areas of Corporate Social Responsibility (CSR) and Compliance were reviewed and responsibilities for specific CSR topics were assigned to all executive board units. A particular CSR and compliance issue here is the German Supply Chain Due Diligence Act (Lieferkettensorgfaltspflichtengesetz, LkSG). When the law came into effect in 2023, Fraunhofer was also subject to the legal requirements for operating a human rights and environmental risk management system in its own business operations and in its supply chain. The due diligence required for this is adapted to the risk situation in compliance programs within the framework of the compliance management system, in accordance with the legal requirements. Further progress was made in 2022 in terms of the organization-wide integration of sustainability criteria into corporate procurement through different measures, which included mandatory training for all procurement personnel. The executive board adopted a declaration of principles on the human rights strategy at the end of 2022.

Declaration of Principles for the Respect of Human Rights

Secure information handling is of fundamental importance to the continued existence of a knowledge-based research organization. At present, the risk of increasing cyber attacks and espionage activities has once again risen significantly in light of the worsening international conflict situation. However, these risks are countered at Fraunhofer with targeted measures and by refining them in the executive board project on cybersecurity.

Cyclic risk management process



Fraunhofer risk classification model

Main risk areas	Specific risk types
Business model	State aid law
	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, advance funding, other financial risks
Resources	HR
	IP, know-how
	Infrastructure
	Financial assets, reserves
	Reputation, brand
Business operations	Service performance, contractual risks
	Legal risks
	Information security
	Governance, internal control systems

Outlook

Despite the economic challenges, Fraunhofer remains financially stable for the 2023 financial year. After a moderate wage increase and long-term supply contracts for energy had a dampening effect on the inflation-related cost increase in 2022, Fraunhofer anticipates stronger cost increase effects for both HR and material costs in 2023. In terms of personnel expenses, employee numbers are expected to increase, while there will be a significantly higher wage settlement compared to previous years. Material expenses will increase noticeably due to the higher energy prices and the general increase in procurement costs. Even with constant investment activity, Fraunhofer expects the financial volume to rise to around €3.3 billion, which is a comparable increase to the previous year. In light of the good current order situation, no financial risk is anticipated for 2023. At present, the planned growth in earnings is already virtually secured due to a high order backlog for the public sector. The situation is a challenging one for industrial revenue, for which even a small absolute increase would represent success bearing in mind the uncertainties shaping the overall economic situation. Accordingly, the financing share of industrial revenue will probably not be able to continue the upward trend of the last two financial years. It is currently difficult to assess how any escalating developments and interactions in the Russia-Ukraine war, the situation on the

energy markets and other economic risks will affect Fraunhofer's business performance.

The executive board initiated the **Emerging stronger from the crisis** strategy project as early as 2021 in order to ensure the long-term expansion of corporate cooperation. This project will explore the future viability and revenue structure of the Fraunhofer R&D portfolio up to 2030. The results will be implemented from 2023 onwards. To this end, the Group portfolios are being further refined to include their subsidiary service offerings and the necessary competencies. Coherent services are developed throughout the value chain. The basis for this is synergies in competencies and intelligent infrastructure pooling in the form of technology platforms. For this to succeed, strategic portfolio coordination within the Group, between the alliances and within the organization as a whole will be stepped up.

In order to advance applied research on **quantum computing**, the Fraunhofer-Gesellschaft founded the centrally coordinated Fraunhofer Competence Network Quantum Computing with corresponding hardware infrastructure as early as 2020: an "IBM Quantum System One" in Ehningen, Baden-Württemberg, with 27 superconducting qubits and a quantum volume of 64. The contractual regulations for the operation of the quantum computer are particularly decisive. They are subject to German law and will comply with European and German data protection regulations, while all project and user data shall remain in Germany at all times. In this respect, Fraunhofer is acting as an enabler for the entire German quantum computing landscape. This is because Fraunhofer not only offers its employees access to the system, but also enables partners from industry and research to use it. Since the current contract with IBM ends at the beginning of 2024, Fraunhofer needs to decide in 2023 whether to continue this cooperation or to negotiate with other providers of quantum computers that have emerged in the meantime.

With the new EU funding period (2021–2027), the 9th EU Research Framework Programme **Horizon Europe** started its active funding phase in 2022. For the first time, the program is focused on EU missions, which aim to promote social change across sectors and come up with measurable solutions within a defined period of time. In line with the Fraunhofer mission, a variety of opportunities for participation are opening up. This applies in particular to the program pillar "Global challenges and European industrial competitiveness", which focuses on future-relevant key technologies. It was clearly already suitable in 2022 as there were 242 newly approved cooperation projects with Fraunhofer participation and a total of 2,628 project partners; Fraunhofer is responsible for project coordination on 24 projects. This trend of intense participation in EU projects is expected to continue in 2023.

The Fraunhofer institutes and research units also provide relevant support for the German Federal Ministry of Education and Research's **Strategy for the Future** of Research and Innovation, which was adopted in February 2023. Many initiatives and projects contribute to digital and technological sovereignty in Germany and Europe. These include the Green ICT@FMD alliance for resource-efficient microelectronics, various chip developments for applications ranging from high-performance computing to post-quantum cryptography, research work and services for national cyber security, and the establishment of a first node in Aachen for a European quantum internet. Since 2022, additional units have been coming into operation to improve health and food security. A couple of examples of this are the Immunology, Infection and Pandemic Research institute branch of the Fraunhofer Institute for Translational Medicine and Pharmacology ITMP at the Penzberg location, and the Fraunhofer Center for Biogenic Value Creatin and Smart Farming with locations in Bavaria and Mecklenburg-Vorpommern. The Fraunhofer AVIATION & SPACE association helps to strengthen critical infrastructures, especially with developments in New Space, and the interdisciplinary Fraunhofer research group "Smart Ocean Technologies" in Rostock operates with the aim of creating a balance between economic use and marine protection. Fraunhofer researchers presented a bioeconomy roadmap at the end of 2022. The recommended actions outline a way in which the performance of German industry can be maintained and increased even in times of multiple global crises and challenges, while at the same time contributing to achieving the climate targets. On numerous delegation visits to explore and conclude new energy partnerships, Fraunhofer experts supported steps to transform the energy system and build a hydrogen economy.

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

The executive board
Prof. Reimund Neugebauer (until May 25, 2023)
Prof. Alexander Kurz
Elisabeth Ewen
Prof. Axel Müller-Groeling
Dr. Sandra Krey

The senate's report on the financial year 2022

Heinz Jörg Fuhrmann, chair of the Fraunhofer Senate until December 31, 2022

Despite multiple challenges facing society as a whole and the simultaneous implementation of two comprehensive internal change processes, the Fraunhofer-Gesellschaft succeeded in stabilizing and slightly increasing its business volume to around €3.0 billion in 2022 (previous year: €2.9 billion), €2.6 billion of which accounts for contract research. This was possible due to the commitment and hard work of around 30,350 employees in 2022.

2022 was characterized by challenges such as the climate and energy crisis, inflation and the war in Ukraine. Just like other organizations and companies, Fraunhofer had to develop strategies and response plans to deal with the energy and gas crisis and its immediate consequences. In addition, the complex SAP introduction had to be continued and a new board structure had to be implemented. This represented two comprehensive internal change processes. The Fraunhofer-Gesellschaft and its around 30,350 employees (in 2022) were nevertheless able to maintain the organization's scientifically excellent and economically stable course.

As the leading research organization in Germany, Fraunhofer digitized all business data and processes in 2022 by implementing SAP. Since the changeover in January 2022, ongoing operations have been characterized by standardized processes as well as automated and optimized solutions. However, the transition has not been without issues. With a total of 46 SAP solutions, 7 partner solutions and 40 SAP cloud applications, the implementation at the Fraunhofer-Gesellschaft represents the largest solution package in the history of the SAP Group. Another comprehensive change process in 2022 was the expansion of the executive board structure to five instead of the previous four executive board units. The objectives of this new executive board structure are to ensure that the responsibilities resulting from the dynamic development of the innovation environment are adequately fulfilled, to refine our expertise, to leverage internal synergies even more effectively, to bolster our scientific excellence both internally and externally, and to broaden and diversify the executive board.

A significant proportion of the research in 2022 focused on further strengthening energy sovereignty. Fraunhofer supports the German federal government's goals for an energy and heating transition, for example, as part of the Heat Pump Initiative, through numerous projects to build a hydrogen economy, including H2GO — National Action Plan for Fuel Cell Production, and by setting up the Fraunhofer Hydrogen Labs.

Photo: Salzgitter AG

The dependencies in microelectronics became just as clear during the years of crisis. With its portfolio of experts from all institutes pooled in the Research Fab Microelectronics Germany (FMD), Fraunhofer represents a pillar of European sovereignty in this key field, particularly within the framework of the EU Chips Act. In 2022, the German federal government once again substantially strengthened this capability with the "Quantum and Neuromorphic Computing (FMD-QNC)" project. The project combines basic research, application and industrial production, supplemented by a new quality of specialist training in a microelectronics academy.

The recent breakthroughs on inertial confinement fusion in the US show that Fraunhofer's mission stretches beyond the transfer of innovation as Fraunhofer provided concrete technological preliminary work for the fundamental experiments that led to these breakthroughs. In 2023, Fraunhofer will establish a team of fusion technology experts to enable German companies to connect with top international researchers in the field of this future technology. Fraunhofer is also supporting the transformation of former coal mining areas with technological initiatives. New innovation ecosystems are to be created in the affected regions by means of technological paths for defossilizing the energy/heating market and digitizing production through sensor technology and artificial intelligence, as well as solutions for the circular economy, especially with a view to the raw materials industry.

This is how the Fraunhofer-Gesellschaft, together with its important partners from science, industry and politics, is significantly contributing to a sustainable, high-performance and sovereign research and innovation system of the future.

The annual financial statements and the management report of the Fraunhofer-Gesellschaft have again received an unqualified audit opinion from the appointed auditing company.

In 2022, the senate fulfilled the duties entrusted to it under the Statutes of the Fraunhofer-Gesellschaft. It convened twice in the course of the 2022 financial year: on May 19 and on October 13. Both sessions took place in a hybrid format.

The main resolutions adopted in accordance with the Statutes concerned the structure of the Fraunhofer-Gesellschaft and matters relating to its executive board:

- Based on the further development of the Fraunhofer-Gesellschaft's executive board structure, a resolution adopted in 2021, the senate elected three new executive vice presidents at its May 2022 meeting on the recommendation of a senate committee for the election and re-election of executive vice presidents commissioned for this purpose: Prof. Axel Müller-Groeling for the Research Infrastructures and Digital Transformation unit (VB), Elisabeth Ewen for the Human Resources, Corporate Culture and Legal Affairs department (VC) and Dr. Sandra Krey for the Finances and Controlling executive unit (VD). The new executive vice presidents took office on August 1, 2022.

- At the senate meeting on October 13, 2022, the senate took note of the information provided by the president, Prof. Reimund Neugebauer, on his intended retirement from the executive board of the Fraunhofer-Gesellschaft on September 30, 2023. Subsequently, the senate established a senate committee for the election and re-election of executive vice presidents and instructed it to fill the position of president and executive vice president for Corporate Strategy, Research and Communications by proposing a suitable candidate no later than the senate meeting in May 2023.

- The senate also decided on changes to its own management structure in accordance with the Statutes. After nine years as a member of the Fraunhofer-Gesellschaft senate — around seven of them as honorary senate chair — I, Prof. Heinz Jörg Fuhrmann, retired from this committee on December 31, 2022, in accordance with the statutes and received the sculpture "The Fraunhofer" as a special award at the senate meeting on October 13. I am as grateful to the Fraunhofer-Gesellschaft as I am to the senate and the executive board for their collegial, constructive cooperation, even in difficult situations. The senate elected their new chair at this October meeting. Hildegard Müller, president of the German Association of the Automotive Industry (VDA), took up the position with effect from January 1, 2023. Kerstin Grosse, managing director of DEROSSI invest GmbH, and Prof. Oliver Zipse, chair of the board of management of BMW AG, were elected by the senate as senate vice-chairs with a term of office starting on January 1, 2023.

- In 2022, the general meeting adopted amendments to the Fraunhofer Statutes, which were noted with approval by the senate. These included, inter alia, the introduction of modern means of communication to ensure that resolutions can be passed and elections can take place in a legally compliant manner in both virtual and hybrid formats.

The senate would like to thank the executive board and the Fraunhofer-Gesellschaft employees for their great commitment and successful work in 2022.

Prof. Heinz Jörg Fuhrmann
Chair of the Fraunhofer Senate until December 31, 2022

"Strong industry is the key to effective climate protection and sustainable economic growth. The only way we can continue to invest so heavily in the restructuring of our economy and in solutions for climate-friendly mobility is with a sound economic foundation."

New chair of the senate

Hildegard Müller
Chair of the Fraunhofer Senate | President of the German Association of the Automotive Industry (VDA)

Hildegard Müller, president of the German Association of the Automotive Industry (VDA), was elected as a senator by the ordinary general assembly in May 2022 and as senate chair by the Fraunhofer Senate at its meeting in October 2022. She started this role at the beginning of 2023. Hildegard Müller has excellent knowledge of the Fraunhofer-Gesellschaft and has already been a member of the Fraunhofer Senate for two terms (2015–2020).

Earlier in her career, the association leader, manager and former politician completed a banking apprenticeship, earned a degree in business administration and worked at Dresdner Bank. Hildegard Müller started her political career as federal chairperson of the "Junge Union" followed by memberships in the federal executive board and the presidential council of the CDU. She was a member of the German parliament from 2002 to 2008, Minister of State to the Federal Chancellor, and was responsible for federal/state coordination in Angela Merkel's first cabinet from 2005 to 2008. In 2008, Hildegard Müller became chief executive officer of the German Association of Energy and Water Industries (BDEW). In the midst of the incipient energy transition, her task was to balance the interests of the members and drive the energy transition forward. From 2016, she worked as executive vice president for Grid & Infrastructure, Innogy SE. Even back then, energy systems integration, and thus also electromobility, was important to Müller.

Since February 2020, Hildegard Müller has been president of the German Association of the Automotive Industry (VDA). With around 650 member companies from all sectors of the automotive manufacturing and supply industry, which together account for over 780,000 jobs, the VDA is one of the largest interest groups in Germany. Müller wants to safeguard this backbone of German and European industry: "Strong industry is the key to effective climate protection and sustainable economic growth. The only way we can continue to invest so heavily in the restructuring of our economy and in solutions for climate-friendly mobility is with a sound economic foundation."

Fraunhofer institutes are supporting these and other transformation processes in the automotive industry with their developments, which include mass production processes to reduce manufacturing costs for battery and hydrogen-based drives. One of the priorities of the Fraunhofer Automobile Production Alliance is to design climate-friendly and affordable products with climate-neutral production.

Photo: Dominik Butzmann

"I like the idea of shaping and developing a leading technical university — especially one that uses interdisciplinary research to develop solutions to global technical and social challenges."

New senate member

Prof. Ulrich Rüdiger
Rector | RWTH Aachen University

Ulrich Rüdiger has been the rector at RWTH Aachen University since 2018. This is a return to his alma mater for the physicist. After his doctorate on magnetooptic storage materials, Rüdiger became a post-doctoral fellow at New York University. During his research stay in the USA, he also worked at the IBM Research Laboratory and the Cornell Nanofabrication Facility (CNF). In 2002, Rüdiger completed his postdoctoral lecture qualification on spin-dependent transport phenomena and then went on to become a professor of experimental physics at the University of Konstanz. He was elected as rector there in 2009 and held this position until he moved to Aachen in 2018. "I like the idea of shaping and developing a leading technical university — especially one that uses interdisciplinary research to develop solutions to global technical and social challenges," says Rüdiger.

Ulrich Rüdiger supports science management processes by serving on several boards of directors, advisory boards, working groups and councils. As such, he was vice president of the German Rectors' Conference (HRK) for research and early career researchers from 2014 to 2018. At the same time, he was a member of the HRK's Permanent Commission for Research in Germany and Europe. In 2012, Rüdiger was awarded the Ordre des Palmes Académiques, one of the most prestigious French honors, for his service to science. He also received honorary doctorates from Taras Shevchenko University and Kyiv National Economic University, both in Kiev.

Rüdiger believes it is important to build bridges from basic knowledge to application and on to the final product, while also holding social discourse with the scientific field in order to manage the fundamental transformation processes. These are challenging tasks that the Fraunhofer-Gesellschaft is also addressing. For instance, RWTH Aachen University and Fraunhofer, among others, founded the Fraunhofer Center for Digital Energy. The purpose of this center is to lay the foundations for technically reliable, hacker-proof and economically attractive digitalized energy infrastructure in the Rhenish mining region and to put them into operation. It also cooperates closely with the Fraunhofer institutes based in Aachen.

Photo: Peter Winandy

"Research is essential in moving industry forward. I have always been fascinated by the interplay between research and industry. Knowledge transfer promotes exchange between the field of research, industry and the political arena, allowing us to promote innovation in society."

New senate member

Prof. Vanessa Wood
Vice president for knowledge transfer and corporate relations | Chair at the Department of Information Technology and Electrical Engineering | Head of the Materials and Device Engineering Group at the Institute for Electronics (IfE) | ETH Zurich

Vanessa Wood started her career in science and knowledge transfer in 2001 with her bachelor's degree in applied physics at Yale University. She then transferred to the Massachusetts Institute of Technology (MIT). She completed her master's degree in the Department of Electrical Engineering and Computer Science there before doing her doctorate with research into optoelectronics. She remained at MIT as a post-doctorate, but transferred to the Department of Materials Science and Engineering where she researched lithium ion batteries.

At the age of 27, Vanessa Wood was appointed professor at the Swiss Federal Institute of Technology Zurich (ETH Zurich). Since 2019, she has been head of the Department of Information Technology and Electrical Engineering. Her primary area of expertise is transport processes in complex materials. A number of awards testify to the relevance of her research: In 2014, Volkswagen and BASF awarded her the Science Prize in Electrochemistry; and in 2018, she won the Outstanding Early-Career Investigator Award from the Materials Research Society for innovative research in visualizing, quantifying and explaining transport processes in materials and devices. Between 2018 and 2020, she was head of the Department of Information Technology and Electrical Engineering at ETH Zurich. In 2021, she was also appointed as vice president for knowledge transfer and corporate relations. In this role, she is responsible for research collaborations and exchange with businesses and policymakers as well as the promotion of entrepreneurship: "Research is essential in moving industry forward. I have always been fascinated by the interplay between research and industry. Knowledge transfer promotes exchange between the field of research, industry and the political arena, allowing us to promote innovation in society," explains Wood.

ETH Zurich cooperates with the Fraunhofer-Gesellschaft on a large number of projects concerning matters such as knowledge transfer. In particular, Fraunhofer institutes have collaborated with ETH Zurich in areas such as battery development and production, quantum technologies and future supercomputing (accelerator units for the chips of the future).

To overview of members, constituent bodies, committees

Photo: Markus Bertschi / ETH Zurich

Review of Fraunhofer research

- New initiatives and infrastructures
- Fraunhofer world records
- Projects and results
- Awards 2022
- People in research
- Transfer activities 2022

New initiatives and infrastructures

New research units

300-mm center: Industry standard microelectronics
The Center for Advanced CMOS & Heterointegration Saxony, whose first stage opened in June 2022, is set to become a beacon of semiconductor research and make an important contribution to securing technical sovereignty in Europe. Thanks to its pioneering 300-mm technology, it is the hub of semiconductor research at the Fraunhofer-Gesellschaft in Germany, taking new semiconductor developments to an industrial level and integrating them into the technology of the top players in the semiconductor industry. The 300-mm heterointegration line planned for the next expansion stage will provide a high-quality laboratory for working on emerging fields such as neuromorphic computing and quantum computing. The Fraunhofer Institute for Photonic Microsystems IPMS (Center Nanoelectronic Technologies) and the Fraunhofer Institute for Reliability and Microintegration IZM (All Silicon System Integration Dresden institute branch) are in charge of managing the center.

Lamarr Institute for Machine Learning and Artificial Intelligence
Five of the six German AI competence centers had previously only received temporary funding. However, as part of the German federal government's AI strategy, institutional funding from the German Federal Ministry of Education and Research (BMBF) and participating federal states was secured in 2022, making them permanent research units. As a result, the former Competence Center Machine Learning Rhine-Ruhr (ML2R) has been expanded to form the Lamarr Institute for Machine Learning and Artificial Intelligence. Researchers are working on high-performance AI applications that are both reliable and resource-efficient. Ethical standards, equal opportunities, diversity and inclusion are guiding principles in all activities at the Lamarr Institute. Naming the institute after the actress and inventor Hedy Lamarr (considered the inventor of frequency hopping technology and inducted into the National Inventors Hall of Fame in 2014) underscores its commitment to the advancement of women. The Lamarr Institute is supported by the Technical University of Dortmund (TU Dortmund), the University of Bonn, the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, and the Fraunhofer Institute for Material Flow and Logistics IML.

Overview of the Fraunhofer structures

Key initiatives

Helping to shape structural transformation
Supporting the structural transformation of former coal mining areas with innovative solutions and knowledge transfer is a critical economic and societal challenge. In 2019, Fraunhofer founded the Mining Network working group, dedicated to the most affected regions of Lausitz, Central Germany, Rhine-Ruhr and Helmstedt. The aim of the working group is to transform former coal mining areas in Germany into model regions for a sustainable industrial society that have an international reputation. There are currently 17 Fraunhofer projects underway in the mining regions, which focus on energy technology, geothermal systems and hydrogen, bioeconomy, microelectronics and lightweight design. They are making an important contribution to the development of an innovation ecosystem while enhancing the attractiveness of the respective locations. Key pioneering technologies were presented at the "Focus journey to structural transformation" event in November 2022.

Heat Pump Initiative for Germany
From 2024, a total of 500,000 heat pumps are to be installed in Germany per year as part of the Heat Pump Initiative, which was launched in June 2022. The German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the German Federal Ministry for Housing, Urban Development and Building (BMWSB) initiated the first heat pump summit in June 2022. A coalition for action was formed to accelerate the heat supply transformation by means of heat pumps. Fraunhofer is supporting the German federal government's ramp-up program for heat pumps. For example, scientists at the Fraunhofer Institute for Solar Energy Systems ISE conducted a field study to investigate the efficiency of heat pumps in existing buildings. The result? Even non-refurbished buildings with radiators (no underfloor heating systems) can, in principle, be heated with heat pumps without the risk of a cost explosion. According to the Near-Surface Geothermal Systems roadmap, 75 percent of the cumulative useful heat demand for space heating and hot water in Germany could be covered by geothermal heat pumps. The same systems could also provide the bulk of the cooling demand, which is rising as a result of climatic conditions. The roadmap was created at the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG.

Deep Geothermal Energy for Germany roadmap
The German federal government has pledged that half of municipal heating will come from climate-neutral sources by 2030. The heating sector accounts for 56 percent of the national energy demand and currently only 15 percent of heating is generated from renewable sources. The advantages of geothermal energy lie in its base load capacity, its sustainability, the fact that it is generally available from local sources and its minimal space requirements, even in confined urban conditions. Under the leadership of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, the "Roadmap for Deep Geothermal Energy for Germany — Recommended Actions for Policymakers, Industry and Science for a Successful Heat Transition" was established in collaboration with the Helmholtz Association.

Research initiative with the United Arab Emirates
In the presence of the German Federal Minister for Economic Affairs and Climate Action, Dr. Robert Habeck, Prof. Mario Ragwitz from the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG signed, on behalf of Fraunhofer, a memorandum of understanding with the Ministry of Energy and Infrastructure (MOEI) of the United Arab Emirates (UAE) in Abu Dhabi. Part of the memorandum of understanding is the promotion of joint R&D projects on energy and sustainability.

Nuclear fusion
If scientists succeed in their quest to harness nuclear fusion, the energy supply will be completely revolutionized. In 2022, major breakthroughs were made in inertial fusion energy (IFE): In a world first, the National Ignition Facility at Lawrence Livermore National Lab (LLNL) in California, US, achieved fusion ignition, creating a burning plasma state. In December 2022, 3.15 megajoules (MJ) of fusion energy were produced from 2.05 MJ of laser input energy. To pave the way for the first fusion power plants, the German Federal Ministry of Education and Research (BMBF) is expanding its corresponding research activities and has established a group of experts for this purpose. Prof. Constantin Häfner is head of the group. The physicist was appointed commissioner of fusion research at the Fraunhofer-Gesellschaft in July 2022 and has been director of the Fraunhofer Institute for Laser Technology ILT since November 2019. Häfner was previously the program director for Advanced Photon Technologies at the LLNL National Ignition Facility. The BMBF group of experts, comprising seven researchers from Germany and abroad, is tasked with investigating how German research and the start-up scene can jointly contribute to global developments in nuclear fusion. The first memorandum is expected in the spring of 2023.

With its lighthouse projects, Fraunhofer is setting strategic priorities for developing specific solutions for the benefit of Germany as a business location. The topics focus on the requirements of the economy.

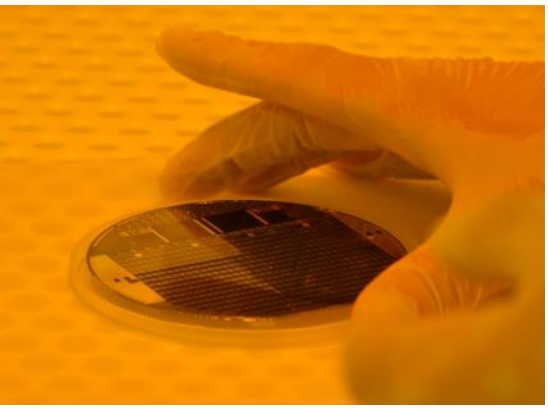
Find out more about lighthouse projects and other higher-level initiatives here

Fraunhofer world records 2022

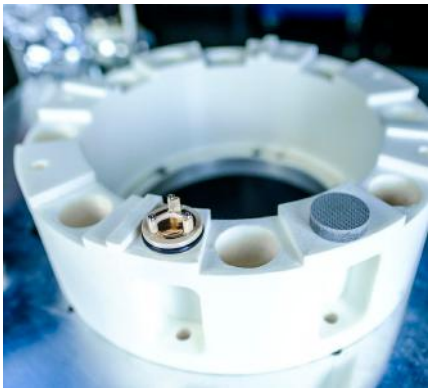
Quadruple solar cell with antireflective coating breaks efficiency records

Researchers at the Fraunhofer Institute for Solar Energy Systems ISE used a new, anti-reflective coating on the most efficient quadruple solar cell to date to increase its efficiency from 46.1 to 47.6 percent with a solar concentration ratio of 665. As it stands, it is the most efficient solar cell in the world. For two years, Fraunhofer ISE has been working on the ambitious 50Prozent project. Funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK), the project aims to develop the first solar cell with 50 percent efficiency. The experts at Fraunhofer ISE aim to use tandem photovoltaics to overcome the limitations of single solar cells, ultimately reducing solar electricity costs.

More information



Currently the most efficient solar cell in the world Photo: Fraunhofer ISE



A milestone for magnetocaloric cooling systems Photo: Fraunhofer IPM

A record for magnetocaloric cooling and heating systems

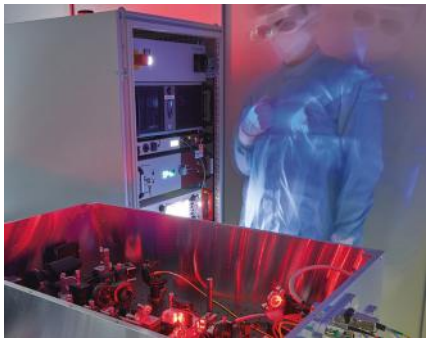
There is an urgent need for energy-efficient, environmentally friendly heating and cooling systems — for refrigerators, for cooling buildings and cars during warm summers, or for heating homes with efficient heat pumps in winter, to name just a few examples. Using a thermal circulation process, the Fraunhofer Institute for Physical Measurement Techniques IPM is developing another method for pumping heat. Laboratory experiments conducted in 2022 were the first to record a power density of 12.5 watts per gram of material used with a heat pump. This means that 200 grams of material could be used to pump 2,000 watts of heat. This world record, which was published in the Nature Communications Physics journal, was made possible by combining thermal processes with the evaporation and condensation of a fluid.

More information

Transferring quantum information with minimal noise

Since 2019, the Fraunhofer Institute for Laser Technology ILT and the Dutch research institute QuTech have been collaborating on optical components for quantum communication and information. They developed a quantum frequency conversion (QFC) architecture that has already demonstrated record-breaking achievements: Their low noise rates and improved signal-to-noise ratio set new standards for transferring quantum information. As such, the research partners have successfully fulfilled one of the prerequisites for rapid connections between quantum computers at different locations, thus paving the way toward a stable quantum internet. Quantum frequency converters are necessary for efficiently converting the wavelengths of photons emitted by qubits to wavelengths that can be transmitted via optical fibers with particularly low loss rates and connected to other qubit systems in heterogeneous networks.

Video of the quantum internet



Laboratory prototype for a low-noise quantum frequency converter
Photo: Fraunhofer ILT

Telescope for quantum communication secure from eavesdropping
Photo: Fraunhofer IOF

Generating quantum keys at multiple kilobytes per second on an international level

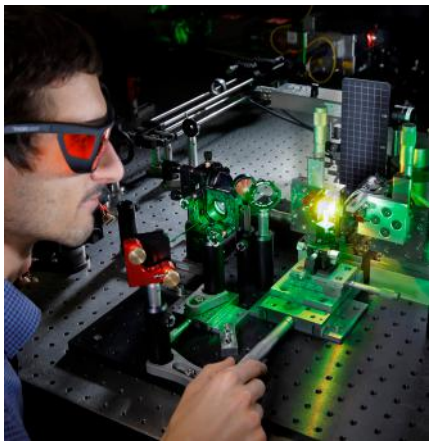
Quantum encryption ensures communication that is absolutely secure from eavesdropping. Since 2021, a local test route has been operated between the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and the Jena municipal utility company, to facilitate the study of quantum key exchanging via free beam — in other words, through the air. Thanks to its telescopes, Alice and Bob, the test route allows researchers to quickly and easily test the latest systems for quantum communication in a real environment — such as photon sources, telescope optics or special measurement systems. The scientists achieved key generation rates in the range of multiple kilobits per second. This generation rate is among the highest in the world for exchanging quantum keys via free beam within an urban area. It would be enough to ensure highly secure encryption of phone calls in a city without issue.

More information

Demonstrating a novel approach to measuring magnetic fields

Experiments by the Fraunhofer Institute for Applied Solid State Physics IAF and an international consortium succeeded in demonstrating the theoretical principle of laser threshold magnetometry for the first time. In this groundbreaking project, diamonds with a high density of nitrogen-vacancy (NV) centers were used in a laser system, demonstrating the world's first measurement of magnetic-field-dependent stimulated emission. Researchers also observed a physical process previously unknown in NV diamonds: the absorption of red light induced by green laser irradiation. The consortium was the first to use NV diamond as a laser medium, allowing them to successfully increase signal power and even set a new record for contrast. The magnetic field-dependent emission was found to have a contrast rate of 33 percent and a maximum output power in the milliwatt range. This only works with diamonds that have both a very high density of NV centers and good optical properties.

More information



A demonstrator for a laser threshold magnetometer *Photo: Fraunhofer IAF*

Wireless data transmission in the 155 to 175 Ghz frequency range
Photo: Fraunhofer HHI

Range record for future 6G mobile communications

Just like 5G, the mobile communications standard of the future, 6G, relies on a modified infrastructure to transmit high data rates in real time. Rather than macrocells, 6G requires microcells for coverage; experts currently consider the sub-terahertz spectrum (155 to 175 gigahertz) to be a likely frequency range. In this scenario, outdoor urban macrocells would be positioned only about 250 meters apart. The Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, the Fraunhofer Institute for Applied Solid State Physics IAF and their industry partner LG achieved a transmission distance of 100 meters for 6G sub-terahertz data during outdoor testing in August 2021. The project partners had already reached the impressive distance of 320 meters during tests conducted at Fraunhofer HHI in September 2022. By using new types of amplifiers on the transmitter and receiver, the technicians were able to more than triple the transmission difference. These new technologies, which have been integrated into LG's latest module design, are ideally suited for future integrated circuit manufacturing — a key factor on the road to commercialization.

More information

Projects and results 2022

The hydrogen economy will primarily use existing, repurposed natural gas pipelines
Image: iStock

Click here to learn more about the Hydrogen Technologies research field

Hydrogen technologies

Using natural gas networks for hydrogen transport

The Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG and other research partners are collaborating with a number of transmission system operators to prepare for the conversion of natural gas networks to a hydrogen transportation system. The new hydrogen network infrastructure will mostly consist of repurposed natural gas pipelines. That is why more than 20 partners are studying the transportation infrastructure within the TransHyDE-Sys research project. This is part of the larger TransHyDE lighthouse project, which is funded by the German Federal Ministry of Education and Research (BMBF). For example, the research groups are conducting detailed simulations of the behavior of key facilities within future hydrogen networks and how they can be integrated into power grids. One area that the researchers are focusing on is the creation of detailed physical-chemical models for all of the mechatronic facilities in the network — including electrolysers, existing compressor stations and natural gas network regulators and, potentially, converted gas and steam power plants. The simulations of the future hydrogen network also cover fuel cell power plants, although these do not yet exist in Germany. The researchers simulate different scenarios so that the behavior of hydrogen can be described in detail. The simulations answer questions such as: How much hydrogen is needed at what time, and where? Where is it generated? How much heat is generated during electrolysis? What is the quality of the hydrogen that is sent through the pipelines? Are there any impurities in the gas that is transported in the network? How does the composition of the gas affect the equipment and drops in pressure? The researchers are also using the simulations to create software modules that will serve as a foundation for further research by the project partners.

By 2050, the projected power demand of over 1,000 terawatt hours must be met by means of a 50:50 mix of hydrogen and synthetic methane or biomethane, in order to achieve the planned defossilization of the gas industry. The experts' investigations have shown that this will make it necessary to split up the transmission system. However, converting the pipeline networks during operation — as is currently taking place in parts of western Germany to allow for a switch from low-calorific

natural gas from the Netherlands to high-calorific natural gas from Norway — will not work for hydrogen.

Producing hydrogen from methanol to power shipping

Shipping is one of the fastest-growing sources of greenhouse gases, and this is leading shipbuilders and operators on a search for environmentally friendly alternative propulsion systems. Researchers at Fraunhofer have joined forces with partners in an EU-funded project to develop the HyMethShip concept, in which hydrogen is obtained from methanol. The energy density of methanol is twice as high as liquid hydrogen, so the on-board methanol tanks would only need to be half the size. Not only that, but transporting methanol is significantly safer than transporting hydrogen. As a result of the provisions of the European Green Deal, cruise ship operators may also be interested in this propulsion system.

Methanol acts as a liquid hydrogen carrier that can be pumped into the ship at port. On board, hydrogen is obtained from the methanol through a steam reforming process and is used for ship propulsion. The system's technical centerpiece is the reactor. The methanol is mixed with water, then evaporated by applying heat and fed into the preheated reactor, where the mix of methanol and water is converted into hydrogen and CO_2. Researchers at the Fraunhofer Institute for Ceramic Technologies and Systems IKTS have developed a carbon-coated ceramic membrane that can be used to separate the hydrogen from the other gases and in constructing the reactor. The hydrogen molecules escape through the extremely fine pores of the membrane, while the larger carbon dioxide gas molecules are retained. The researchers managed to scale the membrane from its original length of just 105 millimeters up to 500 millimeters. Thanks to the membrane, the hydrogen that is fed into the engine has a purity level of over 90 percent. The engine in question is a classic combustion model; however, it does not produce emissions that harm the climate. The developers have also employed some other construction tricks to optimize the prospective process, such as using waste heat from the engine to heat the reactor. What's more, after the reactor process, the remaining CO_2 is liquefied and fed into the empty methanol tanks. When the ship arrives at port, it is fed into tanks and can then be used for the next methanol synthesis process.

Resource Efficiency and Climate Technologies

Exploring geothermal energy with a micro drilling turbine

Geothermal energy has enormous potential to help in the fight against climate change. The water, which can reach temperatures of up to 200 degrees Celsius and be found at depths of up to 5,000 meters, is pumped above ground via boreholes, where it is used for purposes such as driving steam turbines to generate electricity or heating buildings using heat pump systems. Then the cooled water flows back into the earth's crust via a second well, where it is heated up again in the hot rock.

However, drilling these boreholes is expensive and success is not guaranteed, as the exploration risk — i.e., the risk of not finding hot water — is high. The patent-pending Micro Turbine Drilling (MTD®) technology is intended to increase the chances of success during drilling and improve flow rates. The approach: The mini drill goes down the boreholes and drills out into the surrounding earth to depths of multiple meters. This pushes into the surrounding cracks and fissures and opens them up for hot water extraction. The key component of the MTD® is a micro boring turbine with a diameter of 36 millimeters and a length of 100 millimeters. The drill bit consists of a tungsten carbide matrix with diamond punches. It can grind through crystalline rock like granite at a rate of 80,000 revolutions per minute; it can also cut through the steel that is used for lining boreholes. Thanks to its deflection saddle, the turbine can drill out from the main bore at an angle of around 45 degrees. The drilling tool uses this to open up new cracks and fissures with hot water around the main well. The MTD® was developed at the Fraunhofer Research Institution

Top: The integrated membranes in the module for a reactor separate the hydrogen from the carbon dioxide
Photo: Fraunhofer IKTS

Bottom: A micro drilling turbine for geothermal systems
Image: Fraunhofer IEG

Top: CIRCONOMY® Hubs will help circular economy projects join forces *Image: Fraunhofer*

Bottom: Superwood offers a variety of design possibilities
Photo: Studio Sofia Souidi

Click here to learn more about the Resource Efficiency and Climate Technologies research field

for Energy Infrastructures and Geothermal Systems IEG and at the Fraunhofer-Chalmers Research Centre for Industrial Mathematics FCC. The procedure has already gone through successful testing near the Gotthard Tunnel, at the Bedretto Underground Laboratory for Geosciences and Geoenergies in Switzerland. In 2022, the micro boring turbine won a Red Dot Award in the industry devices category.

Networks for a circular economic system

If the circular economy is to succeed, sustainable production, sustainable consumption and closed-loop economic cycles must be implemented in practice. This will require both technical and system-level solutions. In addition, existing initiatives should be combined so that they can benefit from each others' expertise rather than starting from scratch every time. This is why the Fraunhofer-Gesellschaft has taken the network of smaller projects that Fraunhofer institutes are involved in across Germany and started combining them to form CIRCONOMY® Hubs. In this way, it is creating a collective data, knowledge and learning platform that all members of the hubs can access and benefit from. Fraunhofer's transfer-oriented collaboration activities under the CIRCONOMY® brand stem from its voluntary commitment to contribute to the United Nation's Sustainable Development Goals (SDGs).

A number of Fraunhofer institutes have come together to create a charter for Sovereign Value Cycles (SVC), which represents a form of statute for all initiatives cooperating in the CIRCONOMY® Hubs. The charter is based on three strategies for future sustainable production and consumption models: the systematic implementation of circular processes, the creation of sustainable values and the necessity of sovereignty in value creation. The latter strategy will be realized primarily by involving stakeholders from civil society. The first hub, which has already been established, is focusing on circular carbon technology. The members of the hub are working on combining energy and raw material processes, for example, in order to tap into non-fossil carbon sources, to capture carbon or bring it into a circular system and to integrate these technologies into circular energy and economic systems. They will also develop demonstrators for circular carbon technologies (CCT) in local application centers that will be operated in conjunction with industry partners. At the end of 2022, a second CIRCONOMY® Hub was launched, with a focus on establishing a circular economy for construction materials.

Bioeconomy

Eco-friendly superwood for (interior) architecture

Many items of furniture are manufactured out of medium-density fiberboard (MDF), because it is not susceptible to damp or temperature fluctuations, which makes it easy to work with. However, MDF is often treated with binding agents that contain formaldehyde. This is why designer Sofia Souidi and the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI have teamed up to develop eco-friendly, recyclable MDF consisting of recycled waste wood fibers and binding agents made from milk protein.

One of the main challenges in this project was finding a suitable biobased binding agent. The project team decided on a glue made from casein (milk protein), which the ancient Egyptians used as an adhesive for building furniture and boats. Casein can be extracted from milk. To avoid conflicts with food production, the raw materials are obtained from milk that cannot be used on the food market due to hygiene requirements. When casein is combined with waste wood fibers, it forms a material that can be pressed and then processed like MDF — "superwood," as the project partners like to call it. It can be pressed to form boards and molded parts. Pigments and granulates can also be added to the material, which allows for a wide range of design possibilities. Superwood represents an opportunity for wood material industries and sectors such as the furniture, interior architecture, exhibit stand construction and event management industries to comply with the ever stricter requirements regarding

sustainability and formaldehyde emissions. In addition, this recycled and recyclable "super-wood" construction material can also be used as an alternative to plasterboard in interior architecture and the interiors of vehicles such as RVs and trailer homes. To begin with, this collaborative initiative between Fraunhofer WKI and designer Sofia Souidi was funded by the Fraunhofer Science, Art and Design network. The IKEA Foundation provided follow-up funding until mid-2022.

Technologies for adapting to climate change

In multiple projects under the umbrella of the Morgenstadt® (City of the Future) initiative (a registered trademark of the Fraunhofer-Gesellschaft), researchers are investigating the consequences of climate change and developing measures for adapting to them. For example, in Kochi (India), Saltillo (Mexico) and Piura (Peru), scientists are working to adapt city analysis measures to the conditions in newly industrialized countries. This project is being funded through the International Climate Initiative by the German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV).

The effects of climate change are already being felt on a massive level in the coastal city of Kochi in south-west India. The incidence of heat islands in this concrete jungle is increasing, along with flooding due to severe precipitation events. In 2018 and 2019, flooding and landslides caused many deaths and significant damage across the entire city. This is why one of the 15 proposed measures suggests developing a sustainable district with integrated solutions for generating renewable energy, reducing flood risks and treating sewage on a decentralized basis. The district would have green infrastructures for storing rainwater, reducing the strain on sewage systems during severe precipitation events and providing cooling through evaporation. As part of a demonstration project at a government higher secondary school in a district of Kochi, Fraunhofer researchers and regional partners are testing out specific technologies. A special cool roof coating is being applied to sections of the school's roof, greenery is being planted on parts of the facade and a pavilion with rooftop foliage is being constructed in the schoolyard for the students' break times. The sewage from the school, which used to seep out at the site, is now being treated with an eco-friendly process so that it can be used to water the green spaces. In a neighboring district of the city, photovoltaic modules are being installed on 20 rooftops and connected using smart technology, so that the energy supply is more self-sufficient and climate-friendly.

Digital Healthcare

T cells wage war on blood, breast and lung cancer cells

Chimeric antigen receptor T-cell therapy (CAR T-cell therapy for short) is an innovative form of immunotherapy for treating cancer patients. In this form of treatment, genetic engineering is used to turn T lymphocytes taken from the patient into CAR-T cells. These cells' receptors can detect specific antigens on the surface of degenerated cells and trigger a process that destroys them — independently of the immune system's natural ability to differentiate between self and nonself, which cancer cells can often circumvent.

Researchers at the University Hospital of Würzburg have developed a special chimeric antigen receptor to detect the ROR1 molecule that is expressed by cancer cells in leukemia and breast and lung cancer. The genetic material for this special CAR is implanted in the T cells' genome by means of a non-viral genetic process. This reprograms the T cells so that they identify the ROR1-positive cancer cells as "nonself" and destroy them. The Fraunhofer Institute for Cell Therapy and Immunology IZI produced many of the batches of CAR T-cell products for testing and validation. These products were used to optimize the demanding manufacturing process in line with pharmaceutical quality standards (good manufacturing practice, or GMP) and update the assortment list according to the German Medicinal Products Act

Top: A district-wide solution in Kochi, India
Photo: Fraunhofer

Bottom: A scientist selects helper T cells and cytotoxic T cells in one of the first steps toward producing CAR-T cells
Photo: Fraunhofer IZI

Click here to learn more about the Bioeconomy research field

Top: An expert report provided recommendations for speeding up the digital transformation in Germany's healthcare system
Foto: iStock

Bottom: The ScrutinAI software toolkit was developed for analyzing image and video data. It has the power to make the internal actions of AI models visible.
Image: Fraunhofer IAIS

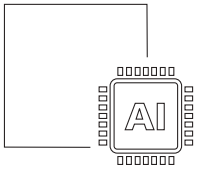
Click here to learn more about the Digital Healthcare research field

(Arzneimittelgesetz, AMG). This resulted in an expansion of Fraunhofer IZI's existing general manufacturing authorization for advanced therapy medicinal products (ATMPs). A preclinical study of the safety and effectiveness of ROR1 CAR T cells was also conducted at Fraunhofer IZI under the conditions laid down in Good Laboratory Practice (GLP) guidelines. This means that the team can now proceed to the next step, i.e., translating the treatment to the clinical domain by means of a phase I/II (first-in-human) study. The project was funded by the Proof-of-Concept initiative. This collaboration program was launched in 2017 by the Fraunhofer-Gesellschaft, the Helmholtz Association and the Deutsche Hochschulmedizin (umbrella organization for German university hospital associations). The goal of the initiative is to accelerate the translation of innovative research projects into practical medicine applications.

Expert report on digitalization in the healthcare system

On behalf of the German government's Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation, EFI), the Fraunhofer Institute for Systems and Innovation Research ISI investigated how much progress has been made in the digitalization of the German healthcare system, and used its findings to recommend courses of action to further drive digital transformation in this area. The focus was on the implementation status of legally required initiatives, the position of the primary stakeholders, data protection and cybersecurity factors, and innovative business models. They also compared Germany's progress with that of Denmark, Estonia, Spain and Austria.

The study identified a number of factors that are delaying Germany's digital transformation, including conflicts of interest between the many stakeholder groups involved, especially bureaucratic groups, an inadequate digital infrastructure in healthcare facilities, security concerns, a lack of reliability as regards the technical solutions, and regulatory uncertainties. According to the results of the study, the legal initiatives from the previous legislative period have laid an important foundation for accelerating the digitalization of Germany's healthcare system. The researchers also recommended additional policy initiatives and measures at the German federal state and government and EU levels — such as the expansion of a powerful broadband infrastructure, the development of an e-health strategy for Germany and a significant improvement in the IT security of healthcare facilities. However, keeping the public informed and increasing digital expertise among healthcare professionals should also be given high priority. The study's comparison with other countries indicated that these countries had involved stakeholder groups to a greater extent in the early implementation stages of e-health processes. This approach can ensure that the implementation is more closely aligned with the actual needs of the healthcare sector, while also providing more support for the healthcare system's digital transformation. The experts involved in the study have recommended that in order to support the digitalization of healthcare in Germany, the changes in question should be monitored continuously and tested through trials at living labs for e-health applications.



Artificial Intelligence

Designing trustworthy AI — securing and assessing AI systems

Artificial intelligence (AI) could be used in all sorts of ways to simplify our daily lives and automate processes — in the automatic analysis of application documents, for example, or image recognition procedures that support quality assurance in manufacturing processes. However, in many cases, AI systems can only really be deemed ready for companies and users to deploy once the systems' trustworthiness, reliability and decision-making processes have been secured and demonstrated. Standards and laws for the demonstrably reliable use of AI, such as the EU AI Act, are already in preparation. The KI.NRW (AI in North Rhine Westphalia) competence platform is also working on a certified AI project with the objective of widespread use

of secure AI. In this project, researchers from the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS have teamed up with partners from the German Institute for Standardization (DIN) and the German Federal Office for Information Security (BSI) to develop standardized testing methods with the "made in Germany" label. Fraunhofer IAIS released an AI assessment catalog back in 2021. This practical document provides companies with a tool that they can use to evaluate and improve their own systems right from the development stage, so as to be prepared for future regulatory requirements. Independent testing organizations can also use the assessment catalog as a basis for product testing.

Some industry partners have already launched concrete testing services based on Fraunhofer IAIS expertise. Since mid-2022, Fraunhofer IAIS have been supporting Munich Re's CertAI service as a technical partner. This testing service for AI applications enables companies to evaluate AI systems in terms of trustworthiness, and thus develop, use or purchase them as needed for their business success. In addition to defining and operationalizing quality requirements, the AI experts at Fraunhofer IAIS are also ensuring that the AI system evaluations conducted through the CertAI service reflect the latest progress in research and development.

Inventory planning helps local pharmacies

Even in 2020, the Federal Union of German Associations of Pharmacists (ABDA) was reporting a steady decline in the number of pharmacies in Germany. However, a direct supply of medications and the opportunity to consult with a specialist in person are still cornerstones of the healthcare infrastructure, and not just for older people. Inventory planning is the decisive factor in enabling local pharmacies to compete with their online equivalents. This is why the Supply Chain Services working group at the Fraunhofer Institute for Integrated Circuits IIS has been researching ways of optimizing this process since the beginning of 2022. The group is concentrating on providing AI-powered predictions of the demand for various medications, taking into account the impact of seasonal factors and patterns, along with the recurring needs of regular customers.

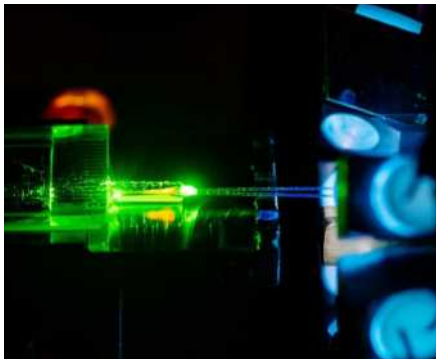
A mathematical optimization model combines the predictions with restrictions such as the storage space and current ordering conditions, so that it can provide the optimal decision for what to order. This makes it possible to serve customer needs directly while simultaneously keeping the amount of capital tied up in stored goods to a low level. The ordering procedure developed in the project is automated to a great extent, which leaves more time for specialist personnel to spend on consultations with customers.

When optimizing pharmacy inventory planning, the research team was able to refer to previous results from projects that focused on wholesale distribution in the sanitation, heating and air conditioning sectors. The pharmacy inventory planning project is being funded until the end of 2024 by the Bavarian Ministry of Economic Affairs, Regional Development and Energy and the Bavarian Collaborative Research Program's (BayVFP) Digitization funding line.

Quantum Technologies

Bridging the gap between classic computers and quantum technology

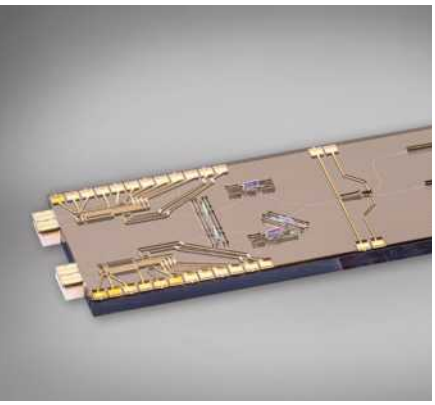
A consortium led by the Stuttgart-based quantum start-up Q.ANT is developing technologies for photonic quantum computing in the project Phoquant. The novel feature in this development approach for harnessing photonic quantum computing in industry settings is that the team hopes to direct, manage and control up to 100 qubits with virtually no losses, even at room temperature. The current generation of quantum computer chips must be cooled to almost absolute zero (–273.15 degrees Celsius), which, in addition to being expensive and difficult, means that they are unsuitable for direct connections with classic computer architectures. The new photonic chip process developed by Q.ANT, a subsidiary of the machine tool manufacturer TRUMPF, is set to make it easier to combine quantum



Top: AI-driven predictions can help optimize inventory management *Photo: iStock*

Bottom: A permanent connection between a glass fiber cable and an integrated optical quantum component
Photo: Besim Mazhiqi / University of Paderborn

Click here to learn more about the Artificial Intelligence research field



Top: Photonic integrated circuit for quantum communication on a PolyBoard platform *Photo: Fraunhofer HHI*

Bottom: Researchers at Fraunhofer IWU collect initial, application-specific training data for the NeurOSmart system AI *Photo: Fraunhofer IWU*

computers with conventional mainframe computers. To do this, the quantum experts have deposited highly specialized light channels on silicon wafers, so that quanta can be transmitted through photonic integrated circuits.

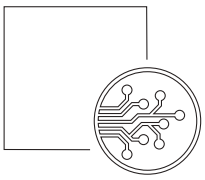
First, the 14 partners are constructing a test facility for photonic quantum computer chips and other quantum computer components. The Fraunhofer Institutes for Applied Optics and Precision Engineering IOF and for Photonic Microsystems IPMS are contributing their expertise here. Fraunhofer IOF and the Friedrich Schiller University Jena are developing some of the essential components for photonic quantum computers, such as integrated optical quantum light sources and low-loss integrated optical and fiber optical interferometers. Meanwhile, Fraunhofer IPMS is developing highly adaptable integrated circuits. These FPGA and ASIC architectures with active interfaces allow for high-precision control and analysis of the photonic quantum computer chip's functionalities. The Phoquant consortium is aiming to present its first prototype by the end of 2024. The goal is to develop a quantum computer chip that can perform a wide range of calculations for industry applications within five years. One of the first use cases the technology will be applied to is real-time scheduling optimization at airports in the event of unforeseen delays. The German Federal Ministry of Education and Research (BMBF) is providing €42 million in funding for the Phoquant project, with the consortium partners contributing a further €8 million.

Pilot lines and test labs for the EU quantum industry

The first phase of the EU's Quantum Flagship project ended in 2022 with numerous successes under its belt, including a prototype for the first scalable trapped-ion quantum computer. This computer, which uses ions as qubit information carriers, was developed at the University of Innsbruck with the assistance of Fraunhofer. Beginning in 2023, the next phase of the EU Quantum Flagship program will be focusing on developing quantum technologies to the point of market readiness and bringing them into application within European industries. These steps are essential for maintaining Europe's technological sovereignty in a highly competitive international economic sector.

The consortia QU-Pilot and QU-Test are jointly organizing the construction of pilot lines for manufacturing quantum components. In addition, they will also give the European quantum industry access to open testing and application labs for experimentation and development procedures. This will allow the companies to test their manufacturing capacities and research and development services for their respective application fields.

QU-Pilot is set to develop the first pre-competitive production processes for quantum technologies and make them accessible to the European industry. In the process, the consortium partners are building on and combining existing European infrastructures. The different pilot lines are tailored to the relevant quantum platforms: superconductors, semiconductors, nitrogen vacancy centers in diamonds, and photonics. Four Fraunhofer institutes are granting access to their manufacturing capacities for this initiative. The QU-Test consortium is building connections between various European testing and application laboratories for quantum technologies. In this consortium, infrastructures distributed across Europe are coming together to combine their unique, globally unrivaled facilities and expertise. Their goal is to support the European quantum industry with the infrastructure and know-how needed to develop and characterize prototypes and products and enable companies to reach market launch more quickly. QU-Test is focused on the following application fields: quantum computers, quantum communication and quantum sensor technology. This consortium will also reap the benefits of the expertise of numerous Fraunhofer institutes.



Next Generation Computing

Sensors learn to think

In the Fraunhofer lighthouse project NeurOSmart, five Fraunhofer institutes have teamed up to research particularly

Click here to learn more about the Quantum Technologies research field

energy-efficient and intelligent sensors for the next generation of autonomous systems. In the process, they are redefining the connections between perception and information processing through innovative electronics.

For them to continue working fairly autonomously in their various areas of application, the robots are packed with sensors and electronics to make them into mobile supercomputers. However, this consumes considerable amounts of energy; according to current predictions, robotic energy consumption will stretch global generation capacity to its limits over the coming decades. This is why Fraunhofer researchers are working on a form of decentralized intelligence that is tailored specifically to each sensor. Neuromorphic electronics are based on a very energy-efficient model: the human brain. Instead of using multiple components that consume a lot of energy in communicating with each other, this alternative approach is based on a new form of analog computer memory technology that can be used to recognize objects and their behavior with great accuracy and in real time.

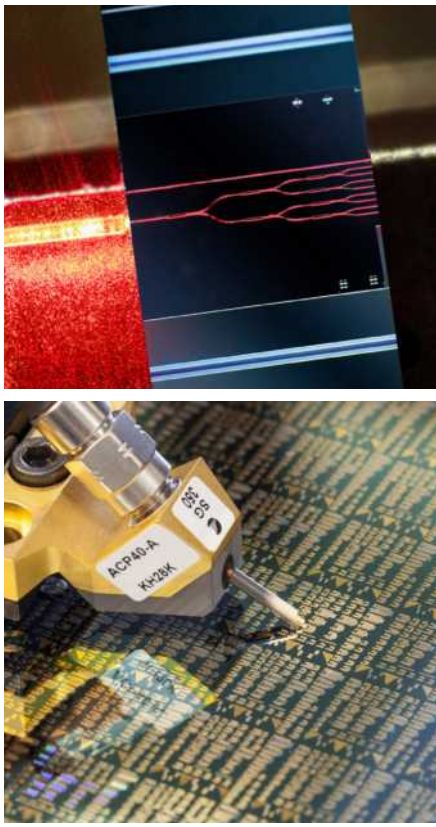
In parallel, the researchers are developing very small, efficient object recognition and classification models that are specially adapted to the sensors, as well as to the new possibilities opened up by directly integrated electronics and their applications. The results are rapid reaction times, improved data protection and significant energy savings when compared to the current trend of cloud-based solutions that tend to rely on ever larger and more energy-intensive models. In the coming years, this approach will be combined with a more complex LiDAR (Light Detection And Ranging) system developed by Fraunhofer and tested in an environment that closely imitates real-world applications. This 3D laser scanning system is crucial for autonomous systems, as it can perceive its environment even in poor visibility conditions and over a wide focus range.

Photonics to secure the Internet of Things

Countless apps are already generating added value for end users, industry, logistics and business, thanks to the Internet of Things and its network of intelligent physical and virtual objects. The number of IoT devices is predicted to rise from 30 to 75 billion by 2025 — meaning there's a more urgent need than ever before to protect the IoT and its applications against cyberattackers. Up to now, this has mostly been done through hardware-based cryptographic algorithms. However, with the rise in communication speeds, the cost and energy budget is increasingly dipping into the negative range here.

A consortium of industry and scientific partners has been working on a novel approach to this problem since 2021, with funding from the German Federal Ministry of Education and Research (BMBF). This project, titled Silhouette, is part of the BMBF's VELEKTRONIK program; the end goal of the initiative is a universal platform solution for developing hybrid systems. One key element of the project is to systematically convert safety-critical electrical signals into optical signals and then process and/or validate them before finally reconverting them to their original form. The photonic transmission channels have the major advantage of being tap-proof and virtually impossible to manipulate. Thanks to the hybrid approach, existing safety-critical components from third-party suppliers can be still be used, which means it will also be possible to retain the current broad range of applications. Other development requirements include low manufacturing costs and the possibility of producing these hybrid electro-optical circuits in batches. The Silhouette consortium's electro-optical platform solution will be based in the European economic area, so that technological sovereignty and reliability are guaranteed at every stage, including during design and manufacturing processes. To achieving manufacturing sovereignty, the researchers will need the simplest and most universal photonic interface possible to existing digital components.

The Fraunhofer Institute for Photonic Microsystems IPMS is coordinating the project along with a number of Fraunhofer and non-university research institutes, OSRAM Opto Semiconductors and qutools, a Munich-based company for developing and marketing quantum optics.



Top: How can we make our electronics more reliable? Light-based data transmission and calculation could be the answer. The circuit shows how this could be designed and manufactured with silicon-nitrogen technology.
Photo: Fraunhofer IZM

Bottom: The AlScN power semi-conductor device opens the door to energy-efficient circuits and components
Photo: Fraunhofer IAF

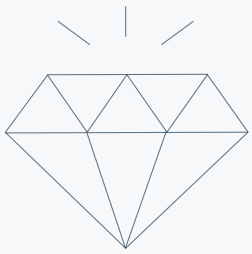
Click here to learn more about the Next Generation Computing research field

Fraunhofer research prizes

Stifterverband Science Prize
Stifterverband is made up of around 3,000 companies, business associations, foundations and private individuals that have come together to drive progress in science and education. For more than 15 years, Stifterverband and Fraunhofer have been awarding this prize, which is worth €50,000, on a biennial basis. This recognizes joint applied research projects of particular scientific excellence that have been developed by Fraunhofer institutes in collaboration with industry and/or other research organizations.

Joseph von Fraunhofer Prize
Since 1978, the Fraunhofer-Gesellschaft has awarded annual prizes to its employees for outstanding scientific achievements that solve practical problems.

Hugo Geiger Prize
The Bavarian Ministry of Economic Affairs, Regional Development and Energy awards the Hugo Geiger Prize for outstanding dissertations written in collaboration with Fraunhofer institutes. The award is named after the Bavarian secretary of state Hugo Geiger, who sponsored the inaugural assembly of the Fraunhofer-Gesellschaft on March 26, 1949.

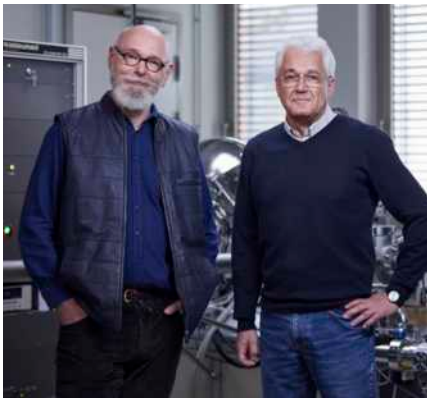


Stifterverband Science Prize 2022

Virtually frictionless — virtual material probe sheds light on the friction gap

In applications such as pumps and compressors, diamond coatings prevent wear in components that rub against each other in mechanical seals, ensuring that these components have a long service life. However, large fluctuations in the friction coefficient can cause damage costing millions of euros. The cause of these high friction coefficients was previously unknown. Prof. Michael Moseler and Prof. Matthias Scherge of the Fraunhofer Institute for Mechanics of Materials IWM, along with Dr. Joachim Otschik of EagleBurgmann Germany GmbH & Co. KG, developed a virtual material probe that can effectively "see into" the friction gap between components as they come into contact — the only one of its kind. This probe gives researchers an insight into what is happening at the atomic level. The jury was particularly impressed by the partners' many years of collaborative research work, which led to the development of the virtual material probe and their understanding of friction phenomena.

The winning project in the Stifterverband Science Prize



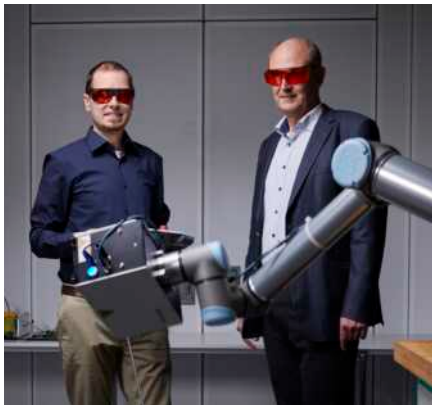
Prof. Michael Moseler and Prof. Matthias Scherge (from left)

Joseph von Fraunhofer Prize 2022

New, precise methods — fluorescence measurement technology for quality control in production

A research team from the Fraunhofer Institute for Physical Measurement Techniques IPM, led by Dr. Albrecht Brandenburg and Dr. Alexander Blättermann, has turned a fluorescence measurement process into a robust, precise measuring technique. For the first time, complex 3D components can be checked for purity during manufacturing in intervals of mere seconds — and these checks cover 100 percent of the component. The performance data is equally spectacular: The system can measure 40 million points per second, detect impurities of just 1 milligram per square meter and take quantitative measurements from 10 milligrams upward. The technology is spreading very quickly, both within Germany and internationally. The jury's decision was motivated by the project's high levels of technical advancement and the quantifiable financial benefits for companies that have adopted the technology.

Video of the fluorescence measurement technology



Dr. Alexander Blättermann and Dr. Albrecht Brandenburg (from left)

Joseph von Fraunhofer Prize 2022

Always ready to receive — RFicient® chips for a sustainable Internet of Things

The number of wireless devices connected to the internet of things is increasing rapidly — in both the private and industrial sectors. However, for devices to be accessible at all times, their radio receivers must be permanently switched on — which runs down the service life of small, battery-powered IoT nodes. In contrast, the RFicient® chip allows for a 99 percent power saving, even though its sensor node is ready to receive signals at any time. This chip was developed by Dr. Frank Oehler, Dr. Heinrich Milosiu and Dr. Markus Eppel and their team at the Fraunhofer Institute for Integrated Circuits IIS. In addition to the complete process chain covering everything from the initial idea to implementation, the project's particular societal relevance was the deciding factor for the jury: After all, the number of wireless devices — together with the associated energy and resource consumption — is skyrocketing.

Video of RFicient®

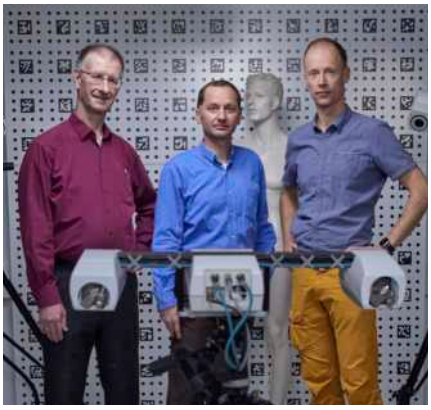
Dr. Heinrich Milosiu, Dr. Markus Eppel and Dr. Frank Oehler (from left)

Joseph von Fraunhofer Prize 2022

A unique measuring technology — 3D-based position monitoring during radiotherapy

When radiotherapy is used to treat cancer, the rays must hit the entire tumors with great precision. However, until recently, monitoring the exact position of patients during treatment has been difficult. Dr. Peter Kühmstedt, Dr. Christoph Munkelt and Matthias Heinze at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF have developed a new overall system to address this issue, in collaboration with their industry partner Varian Medical Systems. In the future, this system will allow doctors to monitor the patient's position to be continuously — both before and during the radiation therapy. The jury's decision to award the prize to this project was motivated in particular by the relief it offers patients. The system's half-millimeter accuracy, high frame rate and low latency were also important factors here.

Video of the radiotherapy measurement technology



Dr. Peter Kühmstedt, Matthias Heinze and Dr. Christoph Munkelt (from left)

Photos: Piotr Banczerowski / Fraunhofer

Hugo Geiger Prize 2022 First prize

Medical application of MEMS micropumps

In her dissertation, Dr. Agnes Bußmann laid the foundations for cost-efficient use of piezoelectric micropumps in medicine. These can be used for administering cancer or pain medication over long periods, treating diabetes, and in 3D bioprinting and organ-on-a-chip applications. Together with Dr. Claudia Durasiewicz, the researcher developed a technology platform that could significantly simplify the technical development and approval process for these types of medical products, which has been very time-consuming and costly up until now. To demonstrate that the technology is suitable for administering drugs, Dr. Bußmann also carried out application-specific experiments focusing on the interaction between the pumps and the media they transported. Thanks to an interdisciplinary approach that combines material science, engineering, electrical engineering, physics, chemistry and medicine, she has increased the cost-effectiveness of this technology and brought it closer to market readiness. Dr. Bußmann completed her dissertation in collaboration with the Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT.

Listen to the podcast here (German only)

Dr. Agnes Bußmann
Photo: Bernd Müller / Fraunhofer EMFT

Hugo Geiger Prize 2022 Second prize

Infrared measurement with quantum sensor technology

In her dissertation, Dr. Chiara Lindner combined Fourier-transform infrared spectroscopy with quantum sensor technology, in collaboration with the Fraunhofer Institute for Physical Measurement Techniques IPM. Using entangled pairs of infrared and visible photons, Dr. Lindner was able to take infrared detectors, which are technologically complex, expensive and limited in terms of quality, and replace them with silicon detectors that are faster, cheaper and quieter. When the photons in the invisible infrared range interact with the sample, the spectral information can be read by the highly sensitive detector via the visible partner photons. This makes it possible to measure the composition of a huge range of samples based on their transmission spectra, quickly and precisely — using only one millionth of the light intensity of conventional spectrometers. In addition to applications in environmental analysis and pharmaceuticals, infrared spectrometers can also open up new possibilities when it comes to testing biological samples. Dr. Lindner had already received the Quantum Future Award 2022 from the German Federal Ministry of Education and Research (BMBF) in recognition of her work.

Listen to the podcast here (German only)

Dr. Chiara Lindner
Photo: Fraunhofer IPM

Hugo Geiger Prize 2022 Third prize

Laboratory-scale synchontrons

Dr. Robert Klas has developed the most powerful source to date for laser-like extreme ultraviolet light (EUV) on a laboratory scale — it is one hundred times more powerful than was previously possible. Short-wave EUV light has huge potential for both manufacture and quality control of high-capacity and energy-efficient microchips and for microscopy of minute organisms in the nanometer range. But generating it is just difficult. By using a sophisticated cascading design based on high-performance ultrashort pulse lasers, the researcher was not only able to design a highly efficient EUV source, but also to simplify its manufacturing process. As a result, it requires only a fraction of the cost of a large-scale research facility (synchrotron), which was previously required for these kinds of experiments, and is easier to operate. This will be a huge driver for research on and with EUV light. Dr. Klas designed the equipment as part of his doctorate in collaboration with the Fraunhofer Institute for Applied Optics and Precision Engineering IOF.

Listen to the podcast here (German only)

Dr. Robert Klas
Photo: Fraunhofer IOF

National and international research prizes 2022

Clemens Dankwerth and Dr. Lena Schnabel (from left). The LC 150 project was awarded second place in the 2022 German Raw Material Efficiency Award. *Photo: Fraunhofer ISE*

German Raw Material Efficiency Award

The Fraunhofer Institute for Solar Energy Systems ISE was awarded second prize in the research institutions category of the German Raw Material Efficiency Award 2022, organized by the Federal Ministry for Economic Affairs and Climate Action (BMWK). The award was presented to the BMWK-funded LC 150 (low charge 150 g) project for its team's work in developing a heat pump refrigerant cycle that runs on propane, an environmentally friendly refrigerant. This innovation could enable propane heat pumps to be used in residential buildings. The researchers at Fraunhofer ISE managed to set a record in October: Using 124 grams of propane (R290), they achieved a heat output of 12.8 kilowatts, which equates to about 10 grams of propane per kilowatt of heat output. Conventional heat pumps on the market use around six times as much fuel.

EU Innovation Prize

RWE Nuclear and the Fraunhofer Institute for Computer Graphics Research IGD won third prize in the waste management category of the EU Nuclear Innovation Prize for their joint research research projects ROBBE (robot-assisted component handling). Since fall 2022, the robot system has been in operation at the RWE dismantling plant in Biblis. At this site alone, there are around 15,000 tons of coated steel parts that require processing. The system ensures that the workers there are exposed to less radiation, and reduces the amount of strenuous physical work they need to carry out. A patent application for the system has already been filed.

The team from RWE Nuclear and Fraunhofer IGD received an EU Innovation Prize *Photo: Fraunhofer*

Nominated for the German Future Prize

The compact ChargeBox enables quick charging of electric vehicles — largely without needing a connection to a powerful electricity network. The storage-based ultra-rapid charging system only needs the standard type of power connection commonly found in residential and commercial buildings. ChargeBox was first developed by the market-listed company ADS-TEC Energy plc (NASDAQ: ADSE) and the Fraunhofer Institute for Solar Energy Systems ISE for the company Porsche AG. This innovation was among the top three nominations for the German Future Prize 2022 — the Federal President's Award for Technology and Innovation.

A team headed by Stefan Reichert, Fraunhofer ISE, worked with ADS-TEC Energy to develop power electronics for the ChargeBox *Photo: German Future Prize*

DECHEMA prize for Prof. Johannes Felix Buyel *Foto: Fraunhofer IME*

2021 DECHEMA Prize

In 2022, Prof. Johannes Felix Buyel of the Fraunhofer Institute for Molecular Biology and Applied Ecology IME, RWTH Aachen University and the University of Natural Resources and Life Sciences in Vienna was awarded the previous year's DECHEMA Prize for his outstanding contributions to producing and isolating active agents using plant systems. Prof. Buyel's work is laying the foundations for the automated production of biopharmaceutical proteins in plants. These proteins will be required for healthcare in the future, in areas such as monoclonal antibodies for cancer treatment or innovative vaccines. Prof. Buyel demonstrated that if cultivation conditions are controlled in a certain way, it will become possible to predict and model transient protein expression in plants. The plant cell pack technology that he helped develop — and the automation this technology enables — means that there is now a high-throughput tool available for plants that can quickly and reliably test hundreds of drug candidates. The system is impressively cost-efficient — the protein expression costs less than 50 cents per protein candidate. At present, Prof. Buyel has published more than 50 peer-reviewed publications (h-index 24) together with scientists from the fields of bioinformatics, biology, biotechnology, laser technology, material sciences and medicine.

Third place in the INNOspace masters competition

At the 2022 INNOspace Masters conference, the Ferrotherm project took third prize in a challenge set by the German Aerospace Center (DLR). In this project, the Fraunhofer Institute for Surface Engineering and Thin Films IST and the Fraunhofer Institute for Chemical Technology ICT are working together to develop a carbon-free method of generating energy through iron combustion and electrochemical recycling. The motivation behind this is the need to secure a long-term energy supply for a planned moon colony, as there are no fossil fuels on the moon. The researchers are investigating the idea of using lunar regolith for iron combustion, with a view to transferring this process to a power plant on Earth further down the line. This technology could significantly contribute to decarbonizing energy supplies.

Dr. Andreas Dietz and Dr. Peter Gräf (from left) participated in the 2022 INNOspace Masters
Photo: German Aerospace Center (DLR)

Ursula M. Händel Animal Welfare Prize

In 2022, this prize went to the Fraunhofer Translational Center for Regenerative Therapies TLC-RT, which is affiliated with the Fraunhofer Institute for Silicate Research ISC and the Würzburg university clinic. The prize was awarded for research into using cell-based tissue models as an alternative to animal testing. The winning team is sharing the prize with Dr. Michael K. Melzer of Ulm University. Researchers at the Translational Center in Würzburg developed tests for predicting toxicity, drug delivery and the efficacy of drugs and chemical substances. The researchers in Würzburg created the test models by cultivating cells in vitro on suitable carrier substances. This resulted in 3D functional models of the relevant barrier organs, which replicate the actual structure of the organ in the body with a high degree of accuracy and can even be used to analyze the development of tumors and investigate treatment methods. As human cells can be used, the level of accuracy in these prognoses is very high, unlike animal testing, which often suffers from poor bioavailability and non-specific targeting.

The winning research team: Dr. Sarah Nietzer, Dr. Gudrun Dandekar, Dr. Daniela Zdzieblo, Dr. Antje Appelt-Menzel, Dr. Florian Groeber-Becker, Dr. Christian Lotz, Dr. Maria Steinke, Dr. Marco Metzger (from left) *Photo: Fraunhofer ISC*

North Rhine-Westphalia Innovation Award

The NRW innovation award was presented in four categories for the first time in 2022. The team that developed SOGNO (Service Oriented Grid for the Network of the Future) was awarded this prize that recognizes special innovative achievements. Prof. Antonello Monti of RWTH Aachen University and the Fraunhofer Institute for Applied Information Technology FIT headed up the project. SOGNO (Italian for "dream") is a complex software platform for distribution grid operators. It uses digital controlling instruments to increase the capacity of the existing grids. The state-of-the-art control technology also helps with substantially reducing the costs of transforming the power systems. The system has proven its effectiveness during field tests. Areti, the grid operator in Rome, has already begun the process of putting the SOGNO architecture into active operation.

The core developments were made in the scope of an EU project in the research group headed by Prof. Monti at RWTH Aachen University. Among those involved in the further development of SOGNO were researchers from the Center for Digital Energy at Fraunhofer FIT.

Prof. Antonello Monti received the North Rhine-Westphalia Innovation Award
Photo: Peter Winand

Click here for more information on the 2022 awards

Dr. Christoph Jürgenhake of Fraunhofer IEM was responsible for developing a holistic design method
Photo: Marius Knutsen / TrAM-Konsortium

Ship of the Year award

Since summer 2022, the first high-speed electric passenger ferry in the world has been operating regular services in Stavanger in southwestern Norway under the name Medstraum. Medstraum (Norwegian for "with electricity" or "continuous current") was built as part of the EU's TrAM (Transport Advanced and Modular) project. The project partners included the Fraunhofer Institute for Mechatronic Systems Design IEM and the Fraunhofer Institute for Industrial Engineering IAO. Building individual ferries is usually an expensive and lengthy process; however, the EU-wide TrAM project consortium is making it faster and more cost-efficient with a modular approach. Basing development and manufacturing around reusable "building blocks" will make shipbuilding significantly faster, more efficient and therefore more competitive. During research into mobility models, the focus was on how land and water transportation can interact in a way that will help bring about climate-neutral and demand-driven urban transportation.

Video of the electric passenger ferry "Medstraum"

People in research 2022

Photo: Heinz Heiss / Fraunhofer

Prof. Katharina Hölzle MBA

Qualified industrial engineer | Member of the institute management for the Fraunhofer Institute for Industrial Engineering IAO in Stuttgart | Director of the Institute of Human Factors and Technology Management (IAT) at the University of Stuttgart

Seeing the silver lining in crises

Innovation is like a muscle, opines Prof. Katharina Hölzle. You have to train to get better at it. She believes that we have lost our mental and physical flexibility due to the high levels of stability, comfort and prosperity we have enjoyed in recent years. As an innovation researcher and industrial engineer, she is maintaining her confidence in the face of the multiple ongoing crises. "As the history of innovation research shows, great advancements in innovation have always come during times of major crisis."

Since April 2022, the professor has been a member of the institute management at the Fraunhofer Institute for Industrial Engineering IAO and director of the Institute of Human Factors and Technology Management (IAT) at the University of Stuttgart. Prior to that, she served as professor for Innovation Management and Entrepreneurship at the University of Potsdam from 2011 to 2019, and then as head of IT Entrepreneurship at the Hasso Plattner Institute. Born in Flensburg in the north of Germany, Prof. Hölzle studied industrial engineering at the Karlsruhe Institute of Technology and completed an MBA at the University of Georgia in Athens. She went on to pursue her doctoral studies at the Technische Universität Berlin, where she also qualified as a professor. Next, the industrial engineer held the role of visiting professor at the University of International Business and Economics (UIBE) in Beijing, the University of Technology Sydney (UTS) and Macquarie University in Sydney. Before launching into her academic career, she worked in companies such as Infineon Technologies, Capgemini and an American start-up. From 2019 to 2021, Prof. Hölzle was a member of the German federal government's High-Tech Forum, and until June 2022, she was the deputy chair of the German federal government's Commission of Experts for Research and Innovation (Expertenkommission Forschung und Innovation, EFI).

She summed up the key points of the report published by the scientists on the expert commission in 2022 as follows: Technological sovereignty is crucial for Germany's growth — "in fact, for our survival, too!" The strength of Germany's positioning varies across the different key technologies, she reports: while the country is doing well in conventional production and material technologies, it has a weak spot when it comes to the areas of bio- and natural sciences. "This is particularly obvious when you look at digital technologies — we have completely fallen behind there." The overall picture that emerged from the studies is a cause for serious concern for the expert council, as digital technologies feature in every form of production and biotechnology these days. Germany ranks much lower than the USA and Asia when it comes to patent applications in this area. China in particular has gained ground enormously, in terms of publications and start-ups as well as patents. "In recent years, Germany has missed out on quite a few things in fields like big data, digital security, microelectronics and AI," states Prof. Hölzle.

Germany's business culture and even its social culture need to change, the scientist asserts. If options are limited, particularly in terms of finances, then old structures must be abandoned in order to make room for the new. "What we need is the desire to shape the future," argues the professor. As a teacher, she treasures her interactions with her students. For her, education means participating and contributing. "Innovations are not welcome in times of doubt. They are stressful, they're different — and we humans really struggle with that kind of thing." However, she insists that each and every individual must accept that "more of the same" is simply no longer an option. The scientist wants to counter that view with another imperative: "I can do something!"

"We can only tackle the great challenges of our time and develop solutions if we pull together, at a social, political, industrial and scientific level. Empowering people for this togetherness — that's what I stand for."

Click here for the online special

Prof. Bruno Burger

Doctor of engineering | Senior scientist in the Power Electronics, Grids and Smart Systems section at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg | Honorary professor at the Institute of Electrical Engineering of the Karlsruhe Institute of Technology (KIT)

Making the most of the sun's power

The scene is Germany, in fall 2022: Gas and electricity prices are skyrocketing, and the German federal government has declared a gas crisis and called on companies, institutions and citizens to adopt energy-saving measures. It was not until the start of 2023 that the German Federal Network Agency and the Federal Ministry for Economic Affairs and Climate Action (BMWK) sounded the all-clear: a severe gas shortage was no longer to be expected for winter 2022/23.

The 2022 energy crisis made Prof. Bruno Burger one of the most "in-demand" scientists at Fraunhofer. The "energy researcher," as the media like to call him, developed the Energy-Charts platform to answer questions such as: What energy sources are used to produce electricity? What does electricity cost at specific times? How much electricity are we importing or exporting? The Energy-Charts track electricity generation data across Europe in real time, based on data sources such as the European Energy Exchange (EEX) in Leipzig and the European Power Exchange EPEX SPOT in Paris, which update their figures hourly. Everyone was looking to Prof. Burger's Energy-Charts for information — from Germany's Tagesschau news program and the Deutschlandfunk radio station through to YouTube channels and broadcaster ARD's business magazine Plusminus.

Prof. Burger has dedicated the last 40 years of his life to renewable energy. Even in his university days back in 1988, he made his student apartment independent from conventional electricity suppliers by installing two solar modules, and built an inverter and a standalone power solution for the room he rented. He and the other three aspiring electrical engineers that shared his apartment looked on in awe as the electricity meter began to run backwards and they started to feed power into the grid. For his thesis on the world's first transformerless inverter, Prof. Burger traveled back and forth by train and folding bike between the Karlsruhe Institute of Technology (KIT) and Fraunhofer ISE in Freiburg, lugging his instruments and equipment along with him. As part of his doctorate, he built a standalone power supply solution for the Höhengasthaus Teufelsmühle guest house in the Black Forest. Prof. Burger's first job was at the Institut für Solare Energieversorgungstechnik ISET (institute for solar energy supply technology), which was affiliated with the University of Kassel and has since become the Fraunhofer Institute for Energy Economics and Energy System Technology IEE. He spent his time there working with the company SMA to develop the Sunny Island inverter — a device which is still in production today.

In 2001, Prof. Burger joined Fraunhofer ISE, which is where he started building the Energy-Charts data portal in 2010. His goal was to create a source of transparent, up-to-date and objective information on the energy transition. As the annual evaluation for 2022 showed, the portion of renewable energy in net electricity generation figures, i.e., the electricity mix that actually comes from a power outlet, reached 49.6 percent last year. Wind energy was the biggest electricity generator in 2022, followed by brown coal, solar power, black coal, natural gas, biomass, nuclear energy and hydrogen. The share of wind and solar power increased significantly. Nevertheless, it was only photovoltaics, which experienced an expansion that the sector had not seen since 2013 and increased its contribution to electricity generation by 19 percent, that reached the expansion goals the German federal government had set for renewable energy.

"Everyone has a part to play in the energy transition," insists Prof. Burger. He and the around 1,400 other employees at Fraunhofer ISE are not giving up on their mission to push solar power's potential right to its limits, as this source of energy is currently the cheapest way of generating electricity in many parts of the world.

Click here for the online special and the Energy-Charts

"We have to leave the age of fossil fuels behind us once and for all and move to renewable energy supplies. There is no alternative."

Photo: Heinz Heiss / Fraunhofer

Photo: Marko Priske / Fraunhofer

Dr. Alethea Vanessa Zamora Gómez

Doctor of engineering | Senior scientist in the Optical Sensors section at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin

A photonic affair

Dr. Vanessa Zamora no longer needs to convince anyone of the usefulness of portable diagnostic devices that deliver rapid results. PCR and antigen tests have shown how important it is to quickly find out whether an infection is present. As lead coordinator of an international consortium, Dr. Zamora played a particularly essential role in developing a prototype for an entirely new generation of diagnostic systems. In 2022, she was able to present the photonic biosensor "PoC-BoSens" at the medical trade show COMPAMED — right on schedule.

As a physics engineer, her expertise was particularly vital to developing the sensor's automatic read-out device — the first to have an entire array of cylindrical microresonators integrated on a single chip. Dr. Zamora, who has been a senior scientist at the Fraunhofer Institute for Reliability and Microintegration IZM since 2019, worked with her team to create an optofluidic configuration that enabled them to connect the hybrid photonic chip with a microfluidic chip. But that's not the only special thing about the system: the microstructures within the read-out cartridge, which are made of optical fibers, can be used for multichannel detection of target molecules. This makes it possible to diagnose multiple diseases simultaneously.

"The most important lesson I learned in my family was to pursue my personal goals with discipline and perseverance," says Dr. Zamora. She comes from a Mexican family with a marked sense of independence and an inclination toward all things scientific. Her mother is self-employed and runs her own micro company, her father worked as an electrical engineer until the day he retired, her elder sister is a specialist in power control at a Mexican gas company and her younger sister is a professor of industry robotics, dynamic systems and cybernetics at a Mexican university. Vanessa Zamora kept up the family tradition and studied physics at the Universidad Autónoma de San Luis Potosí, where she qualified with a masters in applied science. She won an award for being one of the best students in all of Mexico, and then went on to receive one of just 50 doctoral scholarships that the Spanish Ministry of Universities confers worldwide each year. It was at the University of Valencia that Dr. Zamora first worked with optical fibers that could serve as tiny sensors. That was the beginning of her path to becoming an expert in sensor technology — that, and the three months of her doctoral studies that she spent at the Max Planck Institute for Polymer Research in Mainz. For her doctorate, she developed innovative refractometric microsensors based on glass fibers. In 2010, she completed her PhD with honors (cum laude). As a post-doctoral student, Dr. Zamora made a detour to Edmonton, Canada, but as she put it herself, "the way people work in Germany and the facilities they have made a good impression on me."

So she applied to Fraunhofer, and in 2011, she started work at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, as one of the few female experts in her field. It was there that her first patent (US 9,846,060 B1) was issued for an optical resonator array for increasing dynamic range. In 2013, she switched to Fraunhofer IZM. Now Dr. Zamora is a team lead, receiving growing numbers of industry contracts for applications ranging from medicine to quantum technologies. One of her focus areas is miniaturized photonic systems and interfaces with them — optical, electrical, and in the future, fluidic too.

So what does an expert in optical sensors do to relax? She plays volleyball, for one thing: it should be no surprise that she set up a volleyball team for the scientific faculty at San Luis Potosí and led them to second place in a competition. In Berlin, she also plays beach volleyball. "It's a great way to unwind!" she enthuses.

Click here for the online special and additional information

"The Fraunhofer model, with its strong ties to industry, is unparalleled worldwide. With my knowledge of sensors, I can help develop technological solutions that will contribute to the good of society as a whole in the future."

Prof. Michæl Lauster

Aerospace engineer | Commissioned officer | Director of the Fraunhofer Institute for Technological Trend Analysis INT in Euskirchen | Professor for Technology Analysis and Foresight at RWTH Aachen University

Making the future available

"If, before 2019, you had asked me: 'Do you feel safe in Germany?', I would have said: '100 percent!'" observes Prof. Michæl Lauster, deputy spokesperson of the Fraunhofer Segment for Defense and Security VVS. Now, however, the director of the Fraunhofer Institute for Technological Trend Analysis INT would give a very different answer to the question. He has a lot of reasons for this change of heart: from the pandemic and the catastrophic flooding in the Ahr valley and along the Erft river, which destroyed large parts of his institute in Euskirchen, to the war of aggression in the Ukraine and the infrastructure attacks on Nord Stream 1 and the Deutsche Bahn in October 2022. He notes that that there are significant gaps in emergency preparedness: from the lack of masks during Corona's outbreak to community-accurate weather forecasts prior to the 2021 floods, which failed to give appropriate disaster warnings. Prof. Lauster is all too familiar with the consequences these gaps can have. In his own home and in the institute he leads, the basements and ground floors were destroyed. According to the safety and security researcher, critical infrastructures are in particularly grave danger at present, and yet, as he points out, "we live in a country with state-of-the-art resources, such as emergency teams that can reach the scene of a call-out in just seven minutes."

Prof. Lauster not only serves as director of Fraunhofer INT, but also as a professor for Technology Analysis and Foresight at the Faculty of Mechanical Engineering in RWTH Aachen University. He first trained as a commissioned officer in the German army, and then studied ærospace engineering at the University of the Bundeswehr Munich. After completing a doctorate on irreversible thermodynamics, he qualified as a professor in statistics.

Prof. Lauster has been the spokesperson for Fraunhofer AVIATION & SPACE since February 2014. And, as the ærospace engineer is happy to highlight: "Fraunhofer technologies have been along for the ride in one out of every two ESA missions in the last 20 years!" Now, Fraunhofer is playing a vital role both in European space travel and in the protection of critical infrastructures.

The emergence of the private space industry, also known as the New Space movement, is paving the way for solutions in these fields. The resulting development of cutting-edge technologies and increase of private company investments could expand the capabilities of existing satellite systems, offering new options for communication, time and navigation services, as well as earth observation — for example, thanks to fleets of small, batch-produced satellites like the ERNST platform that was developed by the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI. "These kinds of nanosatellites could help us with climate protection and disaster control. Or they could monitor large areas such as submarine communication cables and detect disruptions," explains Prof. Lauster.

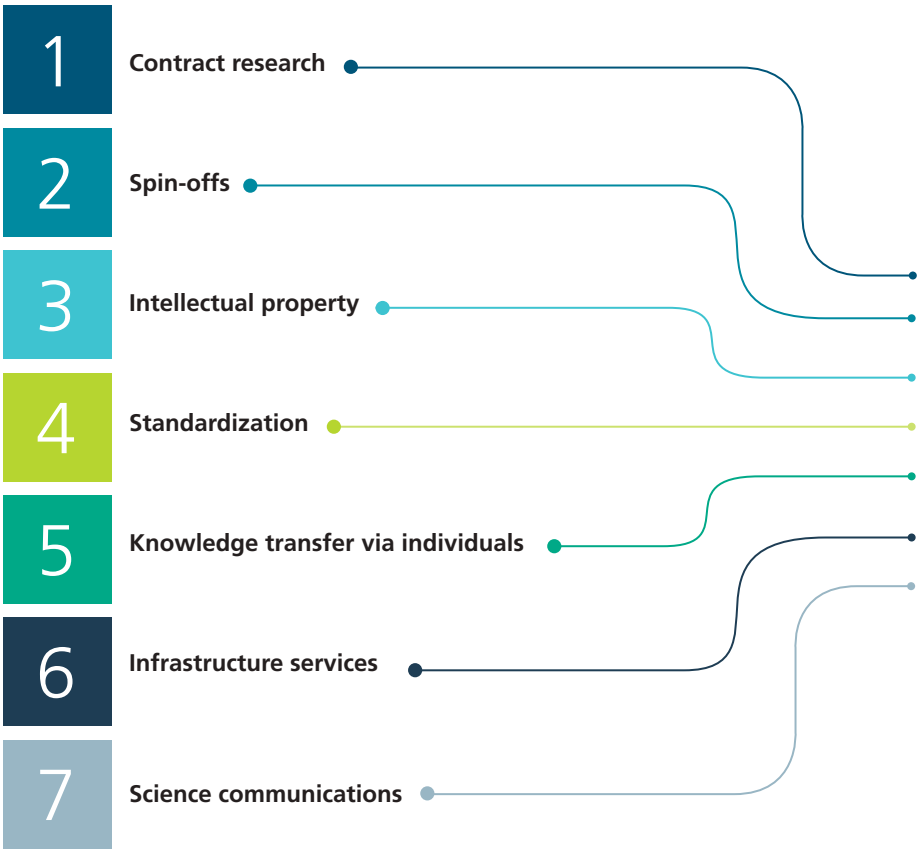
As a safety and security researcher, Prof. Lauster not only views his field from multiple perspectives, but also over long periods of time. "We live in an age where our future is still undecided; it can still be shaped by our actions in the present, so it makes sense for us to consider the threats presented by future events and how we can avoid them." However, the scientist dœs feel that his field is lacking a quantitative theory of safety and security. "If we invest in security architecture, could this allow us to formulate a benchmark that could be used to evaluate the resilience of a system?"

"There can be no doubt that the care we take in making strategic decisions today directly determines what kind of future we will live in tomorrow."

Click here for the online special and additional information

Photo: Marko Priske / Fraunhofer

Transfer activities 2022



Impact on industry and society

Fraunhofer customers bring more new products to the market and increase their sales and returns. Fraunhofer activities have been shown to create jobs in Germany, generate investment impact in the industry sphere and increase government revenue.

Impact of Fraunhofer research

More information, videos and podcasts

Putting research into practice: results find their place in industry and society

Non-university research institutions in Germany are transmitting their efforts to strengthen the country's industry and society via the 7 transfer paths set out in the Pact for Research and Innovation. As the Fraunhofer-Gesellschaft's mission is centered on applied research, the deciding factors it uses in measuring its own success are whether research results are being put into practice, and what impact they are making financially, environmentally and socially.

1. Contract research

Key figures for 2022
€627 million from industry contracts (within Germany and internationally, excluding license-fee revenue)

Commercializing ceramic solid-state batteries
With a research contract for a eight-figure sum and the founding of the joint venture Altech Batteries GmbH: Fraunhofer is well on the way to commercializing ceramic solid-state battery technology. This project was one of the first to be funded by the Fraunhofer Future Foundation. In order to build a battery factory at the Schwarze Pumpe industrial park near the Saxon town of Hoyerswerda, the Altech Group and Fraunhofer founded the joint venture Altech Batteries GmbH. They will use this facility to mass-produce cerenergy®, a platform for ceramic solid-state batteries developed by the Fraunhofer Institute for Ceramic Technologies and Systems IKTS. These resource-efficient sodium-nickel chloride high-temperature batteries can be used to store renewable energy, thus providing what has so far been the missing link of the energy transition. The cerenergy® batteries can be used for grid energy storage when power generation fluctuates, as a buffer between energy generation and consumption, in the charging infrastructure for electric transportation and as a stationary storage solution for industry and private households. Instead of working with critical raw materials such as lithium or cobalt, the batteries use less expensive, readily available resources like aluminum oxide for the ceramic solid-state electrolyte and sodium chloride and nickel for the cathode medium. What's more, the ceramic batteries are fire- and explosion-proof, barely age at all during charging cycles and are 40 percent cheaper to manufacture than comparable lithium-ion batteries, according to the calculations of researchers at Fraunhofer IKTS. Now that the cerenergy® technology is set to go into mass production, shares in Altech have been included in investment recommendations — by Ecoreporter magazine, for example.

2. Spin-offs

Key figures for 2022
18 spin-offs
4 shareholdings

The agriculture of the future begins in space
Data from space will help secure food supplies on Earth and save water in the process: This data will come from a fleet of microsatellites, each the size of a shoe box, that monitor the surface temperature of our planet. Their measurements are accurate to within 50 meters and can provide information on changes in plant health, and enable more efficient irrigation of agricultural land and more precise crop yield predictions. With this information, ConstellR is making huge strides toward a form of agriculture that is adapted to climate change. In March 2022, the technology proved its functionality when the measuring instrument LisR (Long-wave Infrared Sensing demonstratoR) was installed and put into operation on the International Space Station. The data that it has been receiving from and transmitting to Earth since April last year has laid the foundations for a number of pilot projects that ConstellR is currently working on. The development of LisR was led by the Freiburg-based Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI, in collaboration with its spin-off, ConstellR. The measuring instrument consists of a data processing unit and a thermal infrared camera with compact upstream free-form mirror optics that can be used to determine the land surface temperature of the Earth from space. The free-form optics were developed and manufactured by the Fraunhofer Institute for Applied Optics and Precision Engineering IOF and its spin-off SPACEOPTIX. As a prototype, LisR's functionality was put to the test and it passed with flying colors, allowing ConstellR to raise 10 million US dollars in seed capital by the end of 2022. Two ConstellR microsatellites will be launched into orbit in mid-2024, and more will follow in 2025.

3. Intellectual property

Key figures for 2022
7,414 active patent families
443 invention disclosure reports
375 patent applications
€160 million of license-fee revenue

Bowing out with license in hand
In 2022, the Fraunhofer spin-off Arioso Systems was sold to Bosch Sensortec. In 2019, the parent institute, the Fraunhofer Institute for Photonic Microsystems IPMS, and its spin-off, Arioso Systems, concluded a licensing agreement for the technology that it is based on — and this agreement is still in effect. It began with Nanoscopic Electrostatic Drive (NED), a

powertrain technology for micromechanic systems that made the innovative sound transducer possible. To achieve this, the novel MEMS-based NED bending actuators were integrated into MEMS silicon chips, allowing for the production of miniaturized hearables. The advantage of silicon technology is the high extent to which it can be miniaturized. In addition, the electrostatic drive is also energy-efficient.

The NED technology was developed through a collaboration between Fraunhofer IPMS and the Brandenburg University of Technology Cottbus-Senftenberg. The basic patent for the loudspeaker was granted in 2018, and the associated patent portfolio steadily expanded. In 2019, Arioso Systems GmbH was founded as a spin-off of Fraunhofer IPMS, with the aim of bringing the miniaturized headphones and micro-loud-speaker technology to the market. The spin-off got its start as a project of the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation). In the 2020 round of seed financing, which included premium investors such as the High-Tech Gründerfonds, Arioso Systems GmbH received €2.6 million in venture capital. The exit occurred in 2022 when the spin-off was sold entirely to the large German company Bosch Sensortec GmbH, an international leader in the industry and a wholly-owned subsidiary of Robert Bosch GmbH.

4. Standardization

Key figures for 2022
1,235 standardization activities

Regulations for artificial intelligence in cars
There is hardly any other field of technology where artificial intelligence is as safety-critical as it is in autonomous vehicles. There is already a standard for functional safety, ISO 26262, while ISO 21448 focuses on the question of whether the system's design is adequate for a specific situation. Many Fraunhofer institutes have already had representatives in standardization organizations in the automotive sector for years. For example, the Fraunhofer Institute for Cognitive Systems IKS is shaping the future of safe autonomous driving as part of important bodies such as ISO, AUTOSAR, 5GAA and ASAM. One key concern here is the safe use of artificial intelligence, which is the focus of ISO/AWI PAS 8800. Fraunhofer IKS is acting as the international coordinator for the development of this standard. Fraunhofer is also involved with other standardization organizations that work in areas such as future software architecture for vehicles (AUTOSAR) and the safe use of third-party software such as Linux operating systems in vehicles (ISO/AWI PAS 8926). This will allow knowledge from Fraunhofer research to be codified and used in future vehicles.

5. Knowledge transfer via individuals

5.1 Continuing professional development for external specialists and managers

Key figures for 2022
€7.0 million in revenue from Fraunhofer Academy professional development courses (estimated value based on the steady increase in the number of participants)
5,400 participants in 430 courses

Cybersecurity Training Lab for energy and water supply networks
Companies in Germany sustain €203 billion in damages per year due to stolen IT equipment and data, espionage and sabotage. This figure comes from a study conducted in August 2022 by the industry association Bitkom in collaboration with the German federal intelligence services (Bundesamt für Verfassungsschutz). When critical infrastructures such as energy and water supply networks are attacked, the material damage also causes enormous harm to society. It is becoming increasingly difficult to secure supplies: For example, more and more decentralized facilities for data collection and transmission are coming into operation, and the generation, distribution, storage, and use of energy is being controlled by IT-based systems. There are also geopolitical interests involved here. In order to prevent cyberattacks from damaging critical infrastructures, the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB has established a Cybersecurity Training Lab specifically for energy and water supply networks at its Ilmenau and Görlitz locations. Here, scientists are using the findings from their research to develop new methods and procedures for detecting and averting cyberattacks. The applications and prototypes they create are transferred to hardware platforms in the training lab to be tested and validated in a realistic environment. Only then can they be added to training courses or incorporated into the training lab's cybersecurity assessments. In particular, the intensive technical courses on the mobile training platform have attendees ranging from employees to security personnel at energy and water supply networks.

5.2 Employees and careers

Key figures for 2022
65 percent of employees that left Fraunhofer in 2022 were switching to a career in industry (according to exit interviews)

Training future managers
An important aspect of Fraunhofer's mission is ensuring that scientific staff in particular can complete their management

training during their employment at the organization. Fraunhofer has a 10 percent turnover rate in its scientific section. As part of the exit interviews, departing employees were asked where they were planning to go next in their careers. It was found that two thirds of departing employees were switching to careers in industry; around half of these were taking up management positions.

Careers at Fraunhofer

6. Infrastructure services

Key figures for 2022
No figures are available in this area (yet). These can currently be seen in other transfer paths.

Living laboratories for geothermal systems and georesources
Around a quarter of Germany's heating demand could be covered by climate-neutral deep geothermal systems, according to a road map by researchers at Fraunhofer and the Helmholtz Association. A shift to geothermal energy could be particularly effective in North Rhine-Westphalia, as the state is home to the largest district heating networks in Europe that still use waste heat from coal-fired power plants. In order to use renewable energy for district heating, Germany must tap into the large underground thermal water reservoir in Northwestern Europe, as the Netherlands, Belgium and France have already done. The TRUDI living laboratory, run by the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG, is helping to test technologies under realistic conditions, and then quickly and safely scale them up for market launch. In the Fraunhofer Metropolitan Laboratory for Connected Underground Systems and Energy System Transformation TRUDI, heat sources such as solar thermal energy and waste heat are connected to high-capacity thermal storage facilities such as flooded coal mines and high-temperature heat pumps to create heat networks for large cities such as Bochum, which can serve as role models for other locations. In 2022, following a multi-stage selection process by Zukunftsagentur Rheinisches Revier GmbH, the way was cleared for a Fraunhofer living laboratory focusing on deep geothermal systems in the Rhineland region. This could create a large research infrastructure for geothermal energy that is the first of its kind in Europe. At the planned site in Weisweiler, Fraunhofer IEG aims to conduct research with industry partners into areas such as georesources, borehole technologies, exploration and heat storage.

7. Science communications

Key figures for 2022
According to a media engagement analysis, Fraunhofer appeared in 11,026 articles; of these, around 60 percent were initiated by Fraunhofer itself.
They were viewed 5,511.2 million times.

Participation and co-creation
In addition to the traditional communication channels, citizen participation is becoming a more important aspect of science communication at Fraunhofer. Various Fraunhofer institutes have gained experience in the area of citizen science. In order to expand these activities in a structured way, an internal working group of experienced stakeholders from the Fraunhofer institutes was founded. The group is advised and supported by the Public Formats and Initiatives department at headquarters. The Center for Responsible Research and Innovation (CeRRI), a department of the Fraunhofer Institute for Industrial Engineering IAO, is also involved. This department can bring to bear its many years of experience and methodological expertise on the topic of citizen science. In addition to integrating citizen science into its own organization, Fraunhofer is also seeking to engage more actively in dialogue with external stakeholders. For example, Fraunhofer has representatives in the German Federal Ministry of Education and Research's discussion group on participation.

The participation of ordinary citizens is also key when it comes to more efficiently harnessing the potential of digitalization for rural regions. For projects in this area, the Fraunhofer Institute for Experimental Software Engineering IESE supports cities and regions through a co-creation approach. This participatory method means that groups such as citizens, administrators or industry stakeholders are actively involved in collecting ideas, defining requirements, and evaluating strategies and digital solutions that have already been put in place. Fraunhofer IESE's best-known examples of this approach are the Digital Villages ("Digitale Dörfer") and Smart.Rural.Regions ("Smarte.Land.Regionen") projects.

Click here for the quick-start guide for customers.
Here you will find more information on collaboration methods, including for SMEs, opportunities for reciprocal technology transfer and continuing professional development courses.

Finances

- Balance sheet at December 31, 2022
- Income statement for the financial year 2022
- Excerpts from the notes to the 2022 financial statements
- Convenience translation of the German independent auditor's report

Balance sheet at December 31, 2022

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

ASSETS	2022 in €	2022 in €	2022 in €	2021 in € (1,000)
A. Noncurrent assets				
I. Intangible assets				
1. Concessions, intellectual property rights and similar rights and assets	38,394,518.72			12,780
2. Advance payments	1,101,890.39			33,252
		39,496,409.11		46,032
II. Property, plant and equipment				
1. Land, land rights and buildings, including buildings on third-party land	1,596,631,232.09			1,461,941
2. Technical plant and machinery	597,862,593.31			642,086
3. Other plant, operating and business equipment	75,440,824.85			49,377
4. Advance payments and assets under construction	453,751,139.07			427,075
		2,723,685,789.32		2,580,479
III. Financial assets				
1. Shares in affiliated companies	92,782.82			93
2. Shareholdings	9,136,133.83			10,327
3. Securities held as noncurrent assets	8,238,664.30			8,296
4. Other loans	1,245,000.00			265
		18,712,580.95		18,981
			2,781,894,779.38	2,645,492
B. Current assets				
I. Inventories				
1. Raw, auxiliary and operating materials	102,297.23			–
2. Work in progress — 523,038,494.59				527,029
advance payments received –404,278,588.90				–425,125
	118,759,905.69			101,904
3. Advance payments	266,200.12			–
		119,128,403.04		101,904
II. Accounts receivable and other current assets				
1. Trade receivables	271,741,677.41			204,486
2. Receivables from the federal and state governments				
a) relating to base funding 27,834,920.63				39,052
b) relating to project billing, including contract research 335,160,584.93				251,996
c) relating to pension and compensated leave provisions 106,515,200.00				90,132
	469,510,705.56			381,180
3. Accounts receivable from affiliated companies	7,626,772.55			7,760
4. Other current assets	130,984,367.75			110,539
		879,863,523.27		703,965
III. Other securities		512,136,981.52		439,850
IV. Cash and cash equivalents		293,415,664.55		231,980
C. Prepaid expenses and deferred charges			1,804,544,572.38	1,477,699
			30,469,765.05	63,085
			4,616,909,116.81	**4,186,276**
Trust assets			65,669,278.71	8,575

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

EQUITY AND LIABILITIES	2022 in €	2022 in €	2022 in €	2021 in € (1,000)
A. Equity				
I. Non-profit organization capital				
Carried forward	15,453,063.17			15,387
Annual result	72,226.07			66
		15,525,289.24		15,453
II. Reserves for statutory purposes				
Carried forward	15,225.00			19
Transfers	–			5
Allocations	500.00			1
		15,725.00		15
			15,541,014.24	15,468
B. Extraordinary items				
1. License-fee revenue reserve for statutory purposes		404,402,245.99		415,508
2. Grants relating to noncurrent assets		2,770,535,135.62		2,633,936
3. Grants used to finance current assets		379,725,583.09		295,492
4. Extraordinary item for payments from patent sales		128,372,366.67		47,410
5. For financing restructuring measures		21,144,700.00		24,611
			3,704,180,031.37	3,416,957
C. Provisions				
1. Provisions for pensions and similar obligations		8,765,200.00		9,032
2. Other provisions		233,813,533.13		200,065
			242,578,733.13	209,097
D. Liabilities				
1. Trade payables		120,015,092.15		93,898
2. Unappropriated grants from the federal and state governments	319,916,048.27			
a) relating to base funding	164,315,708.66			270,724
b) relating to project billing				150,602
		484,231,756.93		421,326
3. Accounts payable to affiliated companies		768,878.40		–
4. Other liabilities		44,550,157.78		25,241
			649,565,885.26	540,465
E. Accrued expenses and deferred income			5,043,452.81	4,289
			4,616,909,116.81	**4,186,276**

Trust liabilities	65,669,278.71	8,575

Income statement for the financial year 2022

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

		2022 in €	2022 in €	2022 in €	2021 in € (1,000)
1.	**Revenue from base funding**				
1.1	Federal government		876,650,912.72		860,394
1.2	State governments		173,602,948.39		167,310
				1,050,253,861.11	1,027,704
2.	**Revenue from own activities**				
2.1	Revenue from research and development activities				
2.1.1	Federal government: Project funding	767,392,853.79			608,119
	Contracts	29,347,436.74			15,472
2.1.2	State governments: Project funding	265,358,286.45			263,533
	Contracts	9,912,838.59			3,271
2.1.3	Industry, business and trade associations	756,401,562.23			729,838
2.1.4	Research funding organizations and other sources	192,160,537.90			147,064
			2,020,573,515.70		1,767,297
2.2	Other revenue		6,705,859.51		6,498
Total revenue				2,027,279,375.21	1,773,795
2.3	Decrease in work in progress (2021: increase)		–3,990,527.54		32,364
2.4	Other internally constructed and capitalized assets		6,142,686.58		7,508
2.5	Other operating income		38,816,776.44		41,955
2.6	Income from shareholdings		12,058,435.77		2,108
2.7	Other interest and similar income		2,901,454.33		1,030
				55,928,825.58	84,965
Total of base funding and revenue from own activities				3,133,462,061.90	2,886,464
3.	**Change in extraordinary items**				
3.1	License-fee revenue reserve for statutory purposes				
3.1.1	Allocations		–23,820,931.26		–14,754
3.1.2	Reversals		34,926,971.03		14,754
3.2	Grants relating to noncurrent assets				
3.2.1	Allocations (capital expenditure)		–482,260,160.89		–469,931
3.2.2	Reversals (depreciation and amortization)		345,822,410.60		295,203
3.3	Grants used to finance current assets (2021: Grants released through financing of current assets)		–84,233,432.25		29,218
3.4	For financing restructuring measures				
3.4.1	Allocations		–46,000.00		–63
3.4.2	Reversals		3,512,300.00		452
				-206,098,842.77	–145,121
4.	**Total of base funding and revenue from own activities available to cover expenditure**			**2,927,363,219.13**	**2,741,343**

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

		2022 in €	2022 in €	2022 in €	2021 in € (1,000)
Carryover				2,927,363,219.13	2,741,343
5.	**Cost of materials**				
5.1	Expenditure on raw, auxiliary and operating materials	197,204,333.37			214,246
5.2	Expenditure on purchased research and development services	241,060,491.86			235,612
			438,264,825.23		449,858
6.	**Personnel expenses**				
6.1	Salaries	1,438,172,222.75			1,325,824
6.2	Social contributions and expenses for pension schemes and other benefits of which for pension schemes: €67,948,141.64 (2021: €67,927 (1,000))	321,202,027.76			301,287
			1,759,374,250.51		1,627,111
7.	**Amortization of intangible assets and depreciation of noncurrent assets**		344,375,197.50		294,485
8.	**Other operating expenses**		382,832,048.01		368,324
9.	**Amortization of financial assets and securities classified as current assets**		2,166,389.05		864
10.	**Interest and similar expenses**		277,782.76		639
Total expenditure				**2,927,290,493.06**	**2,741,281**
11.	**Net income for the year**			72,726.07	62
12.	**Transfers from reserves**			–	5
13.	**Allocations to reserves**			–500.00	–1
14.	**Annual result**			72,226.07	66
15.	**Allocation to non-profit organization capital**			–72,226.07	–66
				–	–

Excerpts from the notes to the 2022 financial statements

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, 2022 were prepared voluntarily and in accordance with the requirements of the German Commercial Code (Handelsgesetzbuch, HGB) as applicable to large corporate entities. The income statement was prepared in accordance with the total cost method.

The basis of the Fraunhofer-Gesellschaft's accounting method 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 account for grants received from grant authorities, the performance statement for the organization as a whole is reconciled to the revenue and expense statement format used in single-entry bookkeeping by eliminating the effect of cash-neutral income and expense items. The income statement includes these changes in payables and receivables compared with the previous year as well as depreciation/amortization charges. In the balance sheet, these reconciliation items are included under the extraordinary items "Grants used to finance current assets" and "Grants relating to non-current assets." The figures in 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.

	Annual financial statements of the Fraunhofer-Gesellschaft Income statement	Reconciliation to the **revenue and expense statement format** used in single-entry bookkeeping
Balance sheet Management report Notes to the financial statements	Reconciliation between income statement and performance statement	
	Performance statement	
	Budgeted operating expenses and capital expenditure at Fraunhofer-Gesellschaft "Total business volume" level	
	Separate financial statements of the institutes/headquarters	
	Operating budget Costs (excluding depreciation and amortization) Income	**Capital expenditure** Expenses 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 production less depreciation/amortization calculated on a straight-line basis.

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

Institute buildings on Fraunhofer 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 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 noncurrent assets presented in the ordinary accounts are financed by government grants, the extraordinary item "Grants relating to noncurrent 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 production or fair value, whichever is lower. Production costs include applicable personnel expenses, cost of materials, general administrative expenses and depreciation/amortization charges. Advance payments received (including VAT) are openly deducted 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.

Securities classified as current assets 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 in particular for liquidity and risk safeguards.

Funding used to finance noncurrent assets is allocated to the extraordinary item "Grants relating to noncurrent assets." A separate extraordinary item 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 the 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 1.78 percent was used in the calculation in accordance with section 253 (2) 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) 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 2022, pursuant to section 253 (2) HGB. Provisions for partial retirement are calculated on the basis of the policies 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 Fraunhofer-Gesellschaft balance sheet.

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, 2022, the income statement for the financial year 2022 and the full notes to the 2022 financial statements and the 2022 management report.

INDEPENDENT AUDITOR'S REPORT
"To 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., Munich, comprising the balance sheet as at December 31, 2022, the income statement for the financial year from January 1 to December 31, 2022, and the notes to the financial statements, including the presentation of the applied recognition and measurement methods. In addition, we have audited the management report of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V., Munich, for the financial year from January 1, 2022 to December 31, 2022.

According to our opinion, as based on the results of the audit:

- The attached annual financial statements comply in all material respects with the provisions of the German Commercial Code (Handelsgesetzbuch, HGB) as applicable to large corporate entities 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 as at December 31, 2022, and of its operating results for the financial year commencing January 1, 2022 and ending December 31, 2022
- The attached 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 German statutory requirements and provides an appropriate picture of the organization's future opportunities and risks.

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

Basis for opinion

We conducted our audit of the annual financial statements and the management report in accordance with section 317 HGB and the German generally accepted standards for the audit of financial statements set by the Institute of Public Auditors in Germany. 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 other duties in Germany in compliance with the relevant professional code of conduct, with no other connection 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 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. Furthermore, the legal representatives are 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 misstatements, whether due to fraud (i.e., fraudulent accounting manipulations and financial losses) or error.

In preparing the annual financial statements, the legal representatives are also responsible for determining the organization's ability to continue operating as a going concern, which includes disclosing any relevant information concerning this

matter. Moreover, they are responsible for applying methods of accounting that allow assessment of the organization's continuing existence as a going concern, 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 provision of 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 due to fraudulent activities or errors 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 German legal requirements and appropriately presents the opportunities and risks of the organization's future development as well as to issue an auditor's report comprising our audit opinion 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 317 of the German Commercial Code (HGB) and of the generally accepted accounting principles set by the Institute of Public Auditors in Germany (IDW) will always detect a material misstatement when it exists. Misstatements may result from fraudulent activities or errors 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 judgment and maintain a neutral but critical attitude. We also:

- Identify and assess the risks associated with material misstatements in the annual financial statements and management report due to fraudulent activities or errors, 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 that material misstatements resulting from fraudulent activities are not detected is higher than the risk that material misstatements resulting from errors are not detected since fraudulent activities may involve collusion, forgery, intentional omissions, misleading representations, or the override of internal 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 estimated values and the associated information they specify 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 audit evidence, to 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 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 complies with the annual financial statements, meets 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. We have not provided an independent audit opinion on the prospective information or the data on which it 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 controls that we identify during our audit.

Nuremberg, April 28, 2023

Rödl & Partner GmbH
Auditors, tax consultants

Signature: Grässle
Auditor

Signature: Hahn
Auditor

(End of convenience translation of the German independent auditor's report.)"

Services

- Members, constituent bodies, committees
- Structure of the Fraunhofer-Gesellschaft
- Fraunhofer Germany

Members, constituent bodies, committees

Members

The Fraunhofer-Gesellschaft has 1,219 members, comprising 207 ordinary members, 1,004 ex officio members and 8 honorary members. Some members have multiple functions.

Honorary members
Dr. Peter Draheim

Dr. Horst Nasko

Dr. Dirk-Meints Polter

Prof. Ekkehard D. Schulz

Prof. Erwin Sommer

Prof. Klaus-Dieter Vöhringer

Dr. Hans-Ulrich Wiese

Dr. Markus Söder

Senate

Representatives from science, industry and public life
Prof. Heinz Jörg Fuhrmann
Chair of the senate of the Fraunhofer-Gesellschaft

Prof. Birgit Spanner-Ulmer
Deputy chair of the senate of the Fraunhofer-Gesellschaft, director of Production and Technology at Bayerischer Rundfunk

Oliver Zipse
Deputy chair of the senate of the Fraunhofer-Gesellschaft, chairman of the board of management of BMW AG

Dr. Oliver Blume
Chief executive officer of Volkswagen AG and Dr. Ing. h.c. F. Porsche AG

Dr. Roland Busch
President and chief executive officer of Siemens AG

Anja-Isabel Dotzenrath
Executive vice president for gas and low carbon energy and member of the board of directors of BP p.l.c.

Kerstin Grosse
Managing director of DEROSSI invest GmbH

Sabine Herold
Managing partner of DELO Industrie Klebstoffe GmbH & Co. KGaA

Reiner Hoffmann
Member of the European Economic and Social Committee

Pär Malmhagen
Senior advisor

Natalie Mekelburger
President and chief executive officer of Coroplast Fritz Müller GmbH & Co. KG

Bernard Meyer
Managing director of MEYER WERFT GmbH & Co. KG

Tankred Schipanski

Dr. Katrin Sternberg

Dr. Karl Tragl
Chairman of the executive board and chief executive officer of Wacker Neuson SE

Grazia Vittadini
Chief technology and strategy officer of Rolls-Royce

Dr. Anna-Katharina Wittenstein
Member of the supervisory board of WITTENSTEIN SE

Members representing government institutions
Representatives at federal level
Parliamentary state secretary Mario Brandenburg
German Federal Ministry of Education and Research (BMBF)

Undersecretary Dr. Ole Janssen
German Federal Ministry for Economic Affairs and Climate Action (BMWK)

Undersecretary Rita Schutt
German Federal Ministry of Finance (BMF)

Ministerial councilor Dr. Dirk Tielbürger
German Federal Ministry of Defence (BMVg)

Representatives at federal state level
State councilor Tim Cordßen-Ryglewski
Bremen Senator for Science and Ports

Michael Kleiner
Baden-Württemberg State Ministry for Economic Affairs, Labor and Housing Construction

State secretary
Prof. Joachim Schachtner
Ministry for Science and Culture of Lower Saxony

Members delegated by the Scientific and Technical Council (STC)
Prof. Albert Heuberger
Managing director of the Fraunhofer Institute for Integrated Circuits IIS

Stefan Schmidt
Deputy chair of the Scientific and Technical Council of the Fraunhofer Institute for Material Flow and Logistics IML

Prof. Andreas Tünnermann
Chair of the Scientific and Technical Council, director of the Fraunhofer Institute for Applied Optics and Precision Engineering IOF

Honorary senator
Prof. Ekkehard D. Schulz

Permanent guests
State secretary Dr. Katja Böhler
Thuringian Ministry for Economic Affairs, Science and Digital Society

Prof. Anke Kaysser-Pyzalla
Chair of the executive board of the German Aerospace Center (DLR)

Dr. Jens Rosenbaum
Saarland Ministry for Economics, Innovation, Digital Affairs and Energy

Stefan Rughöft
Deputy chair of the Fraunhofer-Gesellschaft central works council, Fraunhofer Institute for Open Communication Systems FOKUS

Prof. Martin Stratmann
President of the Max Planck Society for the Advancement of Science

Prof. Dorothea Wagner
Chair of the German Science Council

Doris Rösler
Chair of the Fraunhofer-Gesellschaft central works council, Fraunhofer Institute for Building Physics IBP

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

Advisory boards

In total, the advisory boards of the institutes consist of 899 members, some of whom hold seats on the advisory boards of more than one institute.

Scientific and Technical Council (STC)

The STC has 113 members, 108 of whom are delegated institute directors or senior managers, while 72 are elected representatives of the scientific and technical staff of each institute.

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

Presidential council

The presidential council of the Fraunhofer-Gesellschaft is made up of the members of the executive board and the chairs of the ten Fraunhofer groups, named below:

Prof. Wilhelm Bauer
Fraunhofer Group for Innovation Research

Prof. Karsten Buse
Fraunhofer Group for Light & Surfaces

Prof. Welf-Guntram Drossel
Fraunhofer Group for Production

Prof. Gerd Geißlinger
Fraunhofer Group for Health

Prof. Peter Gumbsch
Fraunhofer Group for Materials and Components

Prof. Hans-Martin Henning
Fraunhofer Group for Energy Technologies and Climate Protection

Prof. Albert Heuberger
Fraunhofer Group for Microelectronics

Prof. Boris Otto
Fraunhofer ICT Group

Dr. Markus Wolperdinger
Fraunhofer Group for Resource Technologies and Bioeconomy

Presidential council member acting in an advisory capacity
Prof. Jürgen Beyerer
Fraunhofer Segment for Defense and Security VVS

Executive board

Prof. Reimund Neugebauer
(President of the Fraunhofer-Gesellschaft until May 25, 2023)

Prof. Alexander Kurz

Prof. Axel Müller-Groeling

Elisabeth Ewen

Dr. Sandra Krey

Listed information valid as of December 31, 2022

Structure of the Fraunhofer-Gesellschaft

Constituent bodies and their duties

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, acquires its base funding, organizes the distribution of funds among the individual institutes and appoints the institute directors and senior managers.

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

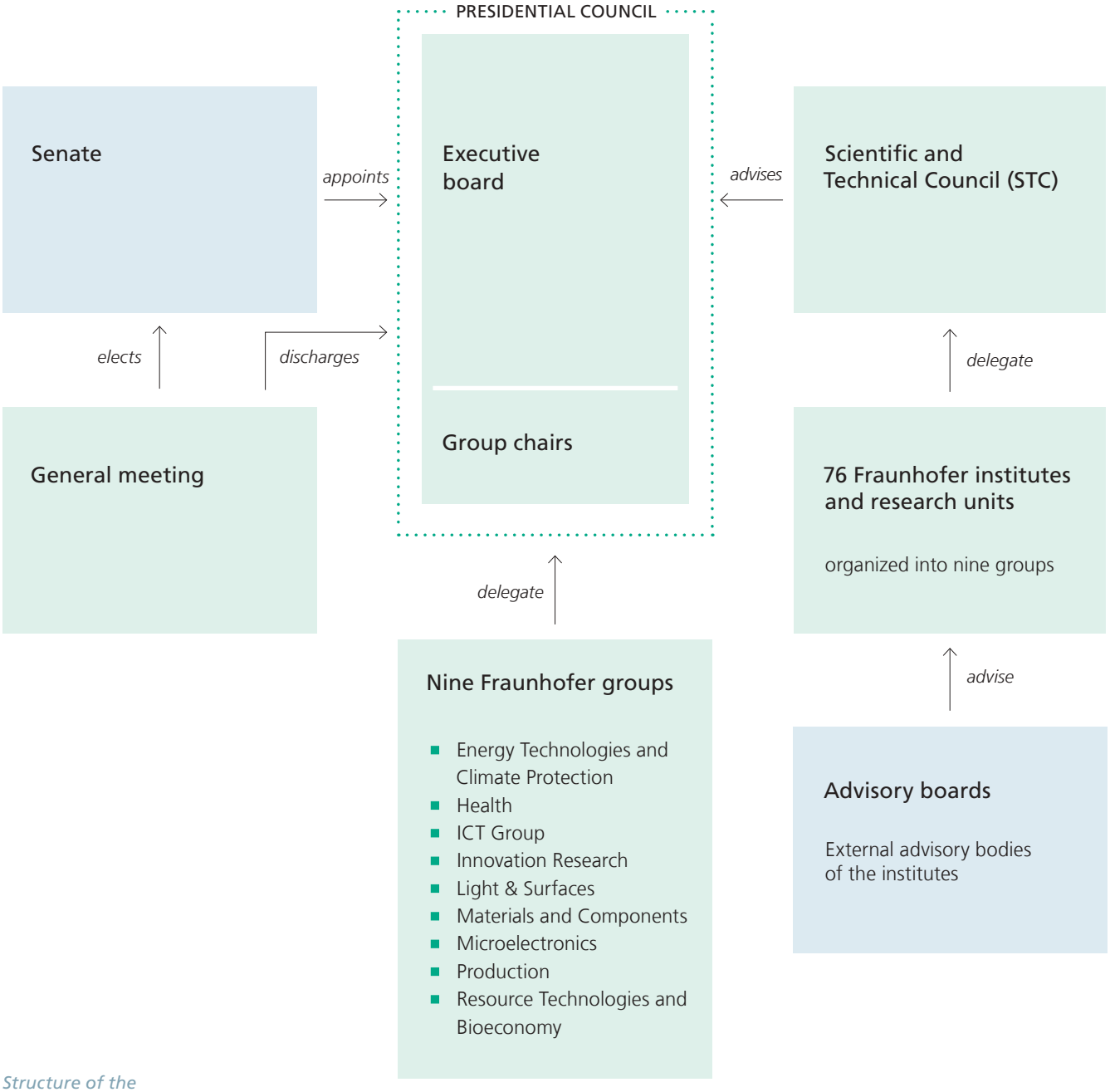
A total of **76 institutes and research units** at locations across Germany operate under the umbrella of the Fraunhofer-Gesellschaft. Each cultivates its own market presence and manages its own budget. They are organized into nine **Fraunhofer groups**, each with a dedicated research focus, and tasked 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 to and has the right to be heard by the board.

The **senate** has around 30 members, comprising eminent figures from the worlds of science, industry and public life, representatives of the German 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 basic principles of the Fraunhofer-Gesellschaft science and research policy, and formulating decisions concerning the establishment, transformation or dissolution of research units belonging to the Fraunhofer-Gesellschaft.

The **general meeting** is made up of the members of the Fraunhofer-Gesellschaft. Ex officio membership is open to members of the senate and the executive board, institute directors and senior managers, 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 meeting elects the members of the senate, discharges the executive board of its functions and formulates decisions concerning amendments to the Statute.

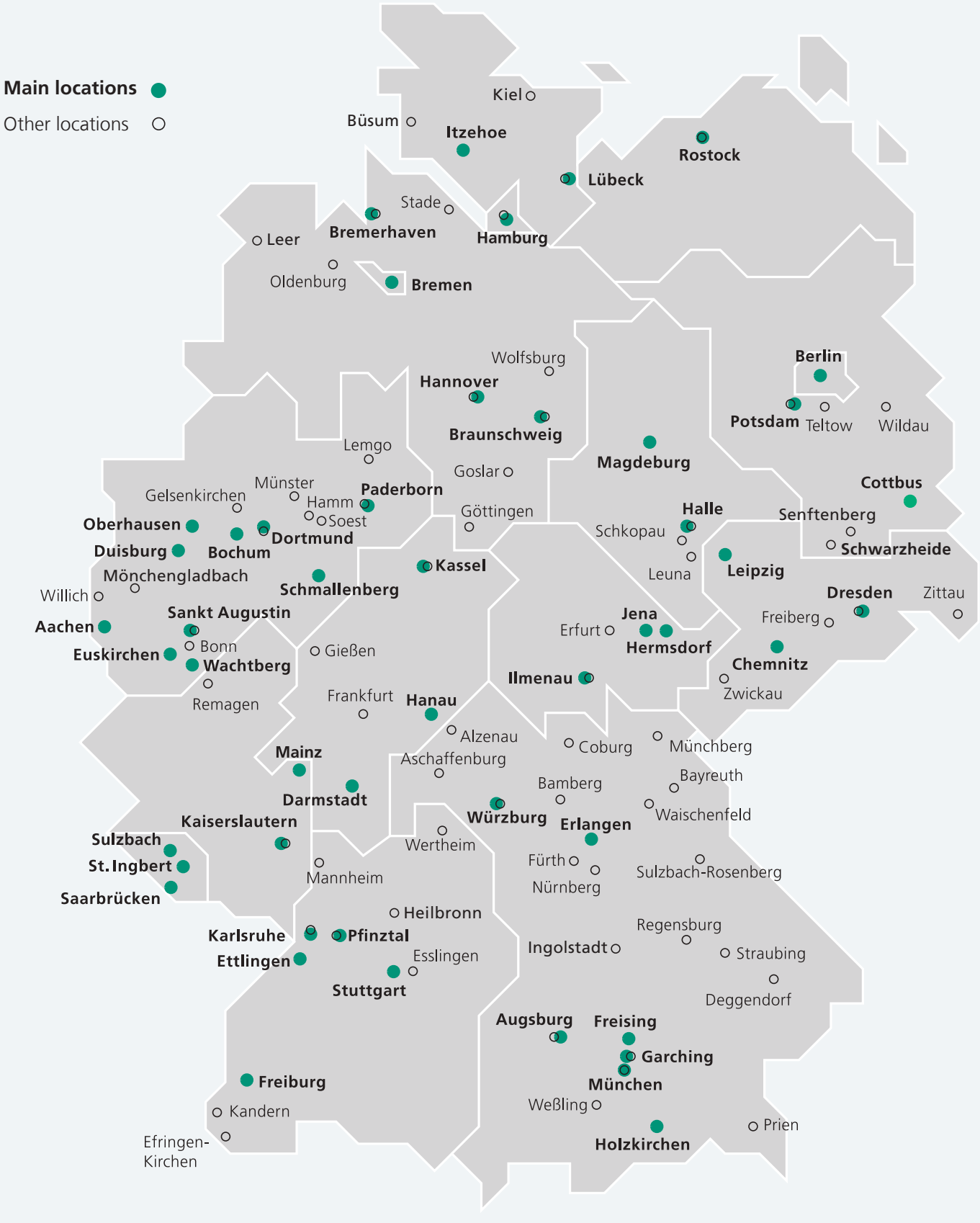
The **STC** is the organization's internal advisory body. It consists of the directors and senior managers of the institutes and an elected representative of the scientific and technical staff of each institute. The STC provides advice to the executive board and other constituent bodies in matters of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

The **advisory boards** are external advisory bodies of the institutes. They consist of representatives from science, business and public life. For each institute, approximately 12 members are appointed to the advisory board by the executive board with the approval of institute management. The advisory boards act as advisors to institute management and the executive board on matters concerning the research focus and any structural changes to the institute.



Structure of the Fraunhofer-Gesellschaft

Fraunhofer Germany



Map of Fraunhofer locations