Fraunhofer

2023 Annual Report

FRAUNHOFER 75 YEARS OF INNOVATION

Fraunhofer at 75 — a cause for celebration …

Dr. Ursula von der Leyen, President of the European Commission

"… because the Fraunhofer-Gesellschaft, more than any other institution, stands for Europe's leading position in applied research. Our unique European research landscape, combined with the internal market and wealth of innovative medium-sized businesses, is the essential driver of growth and forward-looking jobs in Europe. Many thanks for all you do — and keep up the good work!"

Christian Lindner, German Federal Minister of Finance

"… because the cutting-edge applied research of the Fraunhofer-Gesellschaft has been a driver of growth in the German economy for 75 years. Innovative strength and openness to new technologies are the only way forward as we tackle the challenges we face these days. The Fraunhofer-Gesellschaft is setting a brilliant example. It is an important factor in making our country attractive as a place to do business."

Anke Rehlinger, Minister-President of Saarland

"… because the Fraunhofer-Gesellschaft has been harnessing tremendous innovative strength and creative ideas to blaze new trails in science and research for 75 years now. Saarland especially needs this inventiveness and outstanding research findings, paired with the courage to forge new paths, if we are to advance the transformation process. I extend my best wishes to the Fraunhofer-Gesellschaft on its many years of successful work in applied research, which has brought important advances for the whole of humanity and for our local companies."

FRAUNHOFER
75 YEARS OF INNOVATION

Dr. Markus Söder, Minister-President of the Free State of Bavaria

"… because technology is the future! Fraunhofer has been combining cutting-edge research with real-world applications for 75 years and is an international leader in this field. Happy birthday and congratulations on this success! The Free State of Bavaria has been a driving force and close partner right from the start. Fraunhofer and Bavaria form a great alliance, one that we will continue in the future. As part of the Hightech Agenda, Bavaria is currently investing over €5.5 billion in science and research throughout the federal state. In addition to room for 13,000 more students at universities and 1,000 professorships for the brightest minds, we are actively promoting the transfer of knowledge from research to real-world applications. Live long and prosper!"

Bettina Stark-Watzinger, Federal Minister of Education and Research

"… because the Fraunhofer-Gesellschaft has been shaping the German scientific system for 75 years. It conducts research for real-world applications, keeping an eye on new technologies and markets. Fraunhofer stands for successful transfers and a vibrant start-up culture. It dares to make progress. All of this is becoming increasingly important in the face of growing international competition. As a country of innovation, we must not only conduct excellent research but also utilize the results in the domestic economy. The ace up our sleeve is our collaboration and ecosystems with partners from science and industry. The success of the Fraunhofer-Gesellschaft is driven by its employees, who master the balancing act between research and entrepreneurial thinking on a daily basis and are committed to finding solutions"

Michael Kretschmer, Minister-President of the Free State of Saxony

"… because Fraunhofer stands for new beginnings, innovative strength, and excellence in research. And because the Fraunhofer institutes and all their hard-working employees are important sources of fresh impetus, in Saxony and beyond. The research organization was also an instrumental part of the Free State of Saxony's successful development after the German reunification.

Foreword

Dear Reader,

This year has brought a diverse range of challenges, presenting a number of risks and opportunities: security and conflict situations, environmental and resource changes, economic turbulence, and social transformation — all of it demanding responses. These dynamics have become noticeable within the Fraunhofer-Gesellschaft, as elsewhere.

I was elected by the senate in May 2023 to serve as the 11th president of the Fraunhofer-Gesellschaft, a role I took up with great gratitude and respect in August 2023. As part of the Fraunhofer-Gesellschaft, I firmly believe we will play a crucial role in this era of complex change. Our research is focused on solutions and applications, and we are ready and willing to advance the resilience of industry and society through holistic approaches.

For Fraunhofer, the biggest financial development in 2023 was that our total business volume grew to €3.4 billion, an increase of 12 percent over the previous year. Our focus on contract research — which, at 88 percent of our business, is the core of what we do — allows us to develop innovative solutions that already make a crucial contribution to the future viability of industry and society today. Industry contracts are a key factor here, supplemented by publicly financed projects and base funding from Germany's federal and state governments. This makes it possible for us to operate first and foremost as shapers of innovative solutions for industry and to contribute to missions that benefit the whole of society.

Our focus on the Fraunhofer model is vital. Through our applied research and efforts to accelerate transfer in direct relation to customer benefits, we strengthen our unique positioning as a key player in the research and transfer segment. Our partnership with industry not only helps to bolster innovative strength, but also enhances competitiveness for both Germany and Europe.

Fraunhofer has recognized the importance of adjusting its governance structures. Collaboration among key stakeholders, especially the senate, grant authorities, and the executive board, is one way that we ensure we can meet these challenges and modernize our governance in step with the times. Our goal is to foster a corporate culture founded on transparency, responsibility, and community engagement.

We are full of determination and anticipation as we look forward to actively shaping the future of the Fraunhofer-Gesellschaft and advancing our mission. This is all made possible by the hard work, dedication, and support of our valued employees, partners, and grant authorities. Their contributions are essential to our success and ongoing evolution. Together, we will continue to develop innovative solutions, overcome challenges, and explore new horizons now and in the years to come.

Holger Hanselka
President of the Fraunhofer-Gesellschaft

Photo: Fraunhofer / Stefan Obermeier

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The executive board

Prof. Holger Hanselka
President, Executive Vice President for Corporate Strategy, Research and Communications, Acting Executive Vice President for Innovation, Transfer and IP Management

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

Holger Hanselka has been the 11th president of the Fraunhofer-Gesellschaft since 2023. Before that, he was president of the Karlsruhe Institute of Technology (KIT) for ten years and vice-president of the Helmholtz Association for the energy research field. A mechanical engineer by training, Hanselka was the head of the Fraunhofer Institute for Structural Durability and System Reliability LBF in Darmstadt from 2001 until 2013 and was a member of the Fraunhofer presidential council for a time. He is active on various committees that advise the German chancellor on matters of science and research policy.

_____"Transferring scientific findings into applications, solutions, and products for and with German and European industry, especially medium-sized businesses, is what makes Fraunhofer essential. Through its strategic realignment, Fraunhofer is positioning itself for the future and creating guidelines for our future research activities."

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 GMD — Forschungszentrum Informationstechnik GmbH. She has held several management positions in human resources at the Fraunhofer-Gesellschaft, most recently as director of human resources. Ewen has been on the executive board of the Fraunhofer-Gesellschaft since August 2022.

_____"The development of our culture takes place through a participatory, forward-looking, and ongoing, lasting process. Fraunhofer is an attractive employer, and we need to communicate that to the applicant market credibly and authentically and ensure that it is something employees experience for themselves as well."

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 director 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.

_____"Efficiency and performance are the common thread running through all the tasks we need to address together. Optimizing our business processes, advancing the digital transformation and AI, and the goal of achieving climate neutrality at Fraunhofer by 2030 remain some of our key challenges."

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 worked as an auditor at KPMG for several years before joining the MAN Group. She held various leadership positions in accounting and controlling there over a 20-year period. Most recently, she served starting in 2013 as Senior Vice President for Accounting & Finance Processes at MAN Truck & Bus SE and, at the same time, managing director of the MAN Shared Services Center in Poland. Krey has been on the executive board at the Fraunhofer-Gesellschaft since August 2022.

_____"Research is our founding objective. We ensure that our financial resources are spent where innovations emerge from ideas. Ensuring that the Fraunhofer budget is balanced — even with today's subdued economic environment, with costs on the rise and public funding in short supply — is my department's most important task right now."

Photos: Fraunhofer / Stefan Obermeier

2023 management report

Fraunhofer-Gesellschaft — key data for 2023 (in € million)

	2022	2023		Change
Total business volume	**3,049**	**3,404**	**+355**	**+12%**
Contract research	2,615	2,991	+376	+14%
Additional research funding	245	249	+4	+2%
Major infrastructure capital expenditure	189	164	–25	–13 %
Business volume by budget	**3,049**	**3,404**	**+355**	**+12%**
Operating budget	2,567	2,823	+256	+10%
Capital expenditure[1]	482	581	+99	+21%
Project revenue	**2,083**	**2,327**	**+244**	**+12%**
Contract research	1,907	2,167	+260	+14%
of which industrial revenue	787	836	+49	+6%
of which public-sector revenue[2]	1,120	1,331	+211	+19%
Additional research funding	145	139	–6	–4 %
Major infrastructure capital expenditure	31	21	–10	–32%

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

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

Transformation and operating environment

Profile of the Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft is one of the world's leading applied research organizations: 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. 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, while skilled workers earn qualifications** and **modern technology becomes more socially acceptable**.

In 2023, nearly 32,000 people, predominantly scientists and engineers, were employed across 76 institutes with an annual research budget of around €3.4 billion, €3.0 billion of which was designated as contract research. Fraunhofer generated around a third of this from industry contracts and license-fee revenue, totaling €836 million. Another third came from publicly funded research projects. The final share is base funding that is supplied by the German federal and state governments, 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. The Fraunhofer-Gesellschaft also contributes to the success of key technology missions for society as a whole. For public-private partnerships, Fraunhofer is an attractive and established player. 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 collaborate in research fabs and alliances to capitalize jointly on certain business units or sectors. Fraunhofer is currently finalizing a **portfolio coordination process** involving all organizational units within and between the Fraunhofer Groups.

Transformation process to strengthen the Fraunhofer mission

2023 marked the start of a **deep-seated process of transformation** as a **new presidency** got under way. The senate unanimously elected **Prof. Holger Hanselka** to serve as the new president in May 2023, and he took office in mid-August. He was previously the president of the Karlsruhe Institute of Technology (KIT), and up until 2013 had headed the Fraunhofer Institute for Structural Durability and System Reliability LBF.

As one of the world's leading applied research organizations, the Fraunhofer-Gesellschaft **plays a central role in research and transfer activity in Germany and Europe as a whole**. Fraunhofer's knowledge transfer activities mainly revolve around contract research with industry (largest share), exploitation of intellectual property (IP), spin-offs, and transfer via individuals.

The goal is for Fraunhofer to earn one-third of its budget directly with income from the industrial sector. **Its high proportion of industrial revenue makes Fraunhofer unique in the German research landscape**. Direct cooperation with business and industry takes on critical importance as a result, providing ongoing innovative drive and bolstering German and European competitiveness. Base funding reinforces Fraunhofer's scientific expertise, mitigates development risks and shortens time to market, thereby opening up new technological opportunities for companies. **All of Fraunhofer's activities are measured by their stable long-term operation within the Fraunhofer model**. Alongside strong industrial revenue and income from public funding programs, financial security on the part of grant authorities in the form of reliable inflation-adjusted base funding through the Pact for Research and Innovation is a crucial element of this. Going forward, a course of consolidation will be typical of the paradigm shift following a long growth phase. At the same time, Fraunhofer institutes should still have the opportunity to tap into new areas of need across industry and society with topics that fit Fraunhofer and build capability for these activities.

To enable the Fraunhofer-Gesellschaft to effectively fulfill its **business and market-driven mission** for the German innovation system both now and into the future, it is to continue to evolve based on the unique characteristics that already set it apart. Plans call for a rigorous focus on Fraunhofer's core competencies — applied research and the acceleration of transfers, especially in direct cooperation with industry — and building synergistic partnerships within the research landscape.

The process toward a Fraunhofer umbrella strategy for 2030 was launched at the start of 2024. The goal is to use participatory processes to identify the long-term plans and alignment of the Fraunhofer-Gesellschaft at the overarching organizational level. The aim of the umbrella strategy is to set out how the Fraunhofer-Gesellschaft uses its resources to achieve competitive advantages and ensure long-term success within the Fraunhofer model.

Other elements of the **transformation process** include the **further development of modern governance structures and systems** and **transparent compliance** as well as **designing organizational structures for greater efficiency and agility on the basis of a modern, open corporate culture**. These steps are geared toward creating a climate that fosters innovation by top researchers, along with establishing relationships of mutual trust with internal and external stakeholders. A number of different platforms for dialogue between the president and the executive board and various reference groups of employees were launched when Prof. Hanselka took office, in August 2023. The president traveled to multiple locations for **participatory dialogue** with institute directors, staff, and other stakeholders. These activities were accompanied by discussion events held by the executive board at seven institute locations that cut across different fields, institutes, and levels of the hierarchy. Interactive formats (in person and online from September 2023 to March 2024) with different groups of employees form the basis for the development of a **future vision of the Fraunhofer corporate culture**. There are thus multiple interlocking participatory formats pursuing the same goal of picking up on and consolidating ideas and impetus across the organization with the aim of ensuring a forward-looking Fraunhofer culture. In this way, these formats mark a symbolic starting point for the organization's collective evolution.

Science policy framework and positioning

Increased geopolitical and economic conflicts and the challenges posed by climate change influenced developments in 2023. In light of the challenging processes of transformation these trends have brought across business, industry and society, innovations like those Fraunhofer gets off the ground are critical. However, 2023 was also **a year of huge technological breakthroughs in fields such as as generative artificial intelligence (AI), and it brought key advances in digital policy**. Fraunhofer contributes its applied research perspective to the ongoing discourse around research policy to help improve overall conditions and make them more innovation-friendly and to accelerate and streamline the transfer of knowledge and technologies.

2023 marked a change of direction in German federal budget policy, which will also affect the financing of projects falling within the realm of research policy. The German federal budget for 2024 includes a return to **compliance with the debt brake** mechanism after the increased financial outlays made during the crises of the past few years, which will mean cuts in investment. This is especially true of the budgets of the German Federal Ministry of Health (BMG) and the Federal Ministry for Economic Affairs and Climate Action (BMWK). By contrast, the German Federal Ministry of Defence (BMVg) will see its budget increase, including funding for defense research. The budget for the German Federal Ministry of Education and Research (BMBF) is holding steady from last year, but it will involve reductions in external funding for quantum technologies, artificial intelligence, and life sciences in the research sector. **Despite these cuts, the base funding for non-university research organizations will remain stable**. The base funding allocated to the Fraunhofer-Gesellschaft from the German federal budget has been reduced only slightly compared to 2023. In all, Fraunhofer will receive some €940 million in base funding out of the federal budget. The German Federal Constitutional Court's decision on the financing of the Climate and Transformation Fund (CTF) is expected to bring cutbacks in funding for research and technology, including across various hydrogen applications and in the battery segment.

The objective of the German federal government's **Future Strategy** is to strengthen the German innovation ecosystem. The government has stressed the importance of supporting the transfer of innovative research findings into application. The Fraunhofer-Gesellschaft formulates science policy positions on the individual missions of the Future Strategy (circular economy, digital sovereignty, health and more) and incorporates them into the further process of crafting the strategy.

The **digital transformation** offers great competitive potential for Germany as a hub of innovation. Data plays a strategic role in this as a key resource for **data-driven innovation**. This makes simple and secure access to high-quality data without a lot of bureaucratic red tape a key prerequisite for Germany's position as a hub of research. The Fraunhofer-Gesellschaft has taken positions in various policy fields to ease access to data for research purposes. For example, Fraunhofer formulated **science policy positions on the German Mobility Data Act (Mobilitätsdatengesetz), Research Data Act (Forschungsdatengesetz),** and **Health Data Use Act (Gesundheitsdatennutzungsgesetz)** and contributed them as part of the legislative process.

The topic of generative AI moved to the forefront of science policy debate in 2023. Owing to the disruptive potential of generative AI and the fast pace of global developments in this field, rapid and coordinated action across the entire innovation system is needed. There is great potential for value creation in the area of business model development in particular, due to the existing expertise and wealth of industry-specific data on hand in Germany and Europe as a whole. The Fraunhofer-Gesellschaft has both the technological expertise and the long-standing experience in use case development to support this process. On that basis, **the German chancellor's Zukunftsrat (Future Council)** in 2023 gave the Fraunhofer president, together with SAP and the Max Planck Society, a mandate to serve as **sponsors for the topic of generative AI**. Under the auspices of acatech — National Academy of Science and Engineering and in close cooperation with the other topic sponsors, a dossier was created to highlight the challenges and opportunities associated with generative AI in Germany and identify recommended actions for the German federal government. These results were presented to the federal government at the meeting of the Future Council in January 2024. The Fraunhofer-Gesellschaft also participates in the policy debate surrounding generative AI at the state and federal levels and points out strategies that are open to innovation with an eye to empowering German business and industry to harness the potential of this new technology on a broad basis.

Fraunhofer was instrumental in the drafting of a dossier on the **circular economy** as part of the **Alliance for Transformation (German federal government's central dialogue platform)** in 2023, with a large number of institutes involved. The dossier focused on circular concepts for the construction and battery sectors, which are both key industries for the mobility and energy transition. Together, the drafters crafted suggestions for actions to take through cooperation between business and industry, the research sector, government, social partners, and civil society. The recommendations highlight ways that Germany could accelerate the establishment of a circular economy while at the same time reducing its dependence on imports of key raw materials. They were discussed with the federal government at the final meeting, which was held in January 2024.

The Alliance of Science Organizations in Germany worked in 2023 on relevant topics in innovation and research policy that reflect current issues of importance across the whole of society. Examples include the **German Academic Fixed-Term Contract Act (Wissenschaftszeitvertragsgesetz), Bureaucracy Relief Act (Bürokratieentlastungsgesetz), Energy Efficiency Act (Energieeffizienzgesetz), KRITIS Umbrella Act (KRITIS-Dachgesetz)** and **Lobbying Register Act (Lobbyregistergesetz)**. Within the Alliance of Science Organizations in Germany, the Fraunhofer-Gesellschaft actively contributed to drafting position statements and to association hearings and positioning on challenges in science policy.

International activities

The 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 the respective partner country. Fraunhofer has developed various formats for generating excellent scientific content and collaborating 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.

The international affiliates act as legal entities for 11 research centers outside of Germany. 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.

There has been a changing of the guard at **Fraunhofer Austria**, as Prof. Sebastian Schlund was appointed to succeed Prof. Wilfried Sihn as managing director. The Fraunhofer Austria Center für Data Driven Design (DDD), which has locations in Graz and Klagenfurt, also successfully passed an evaluation and audit in July. The audit is a prerequisite for the three-year continuation of the start-up financing provided by the Austrian state of Carinthia for the DDD office in Klagenfurt.

Prof. Raoul Klingner was appointed to serve as the new chairman of the board of directors of Fraunhofer USA.

An **application** to create a Spanish Fraunhofer foundation as a legal umbrella organization **for a Fraunhofer center in Barcelona** was filed in 2023. The official process of registering with the Spanish authorities is currently under way. The partner institute for the planned new center is the Fraunhofer Institute for Biomedical Engineering IBMT, which plans to begin working with the Institute for Bioengineering of Catalonia (IBEC) on an institutional basis in the area of applied theragnostics. Plans call for the necessary development and base funding for the new center to come 100 percent from Spanish sources.

Both **Fraunhofer Portugal** centers, the Center for Assistive Information and Communication Solutions AICOS and the Center for Advanced Water, Energy and Resource Management AWAM, underwent a **strategy audit** in October 2023. Results for both were positive, and a **continuation recommendation** for the coming funding period was issued to the grant authorities (Fundação para a Ciência e a Tecnologia FCT and the Fraunhofer-Gesellschaft).

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. After two several-stage calls for tenders in 2023, there are now four FIPs in preparation, with plans to establish two in South Korea and one each in Taiwan and China in 2024.

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 ICON projects were launched in 2023:

The Fraunhofer Institute for Solar Energy Systems ISE began collaborating in March 2023 with the University of Strathclyde, in the UK, on an ICON project titled **GreenCom — Green Optical Wireless Communications Facilitated by Photonic Power Harvesting**. The project aims to complement LiFi (Light Fidelity) optical wireless communication with photonic energy harvesting. The goal is to improve energy efficiency in communication networks to enable connectivity that is both ecofriendly and blazing fast.

The Fraunhofer Institute for Wind Energy Systems IWES is cooperating with France Energies Marines in a project titled **NEMO — New methods for turbulence measurements and models in offshore wind**. A new measurement and modelling methodology for the characterization of wind turbulence should enable a better evaluation of locations for offshore wind energy use.

Another ICON project, **Simplified Safety Assessment of Cobots with a Fast Contact Model (SafeCoM)**, was launched with Kyung Hee University (KHU), in South Korea, in October 2023. Its goal is to digitalize safety assessments (collision measurements) of collaborative robots (cobots) for applications in production and in the fields of machinery and healthcare. For model development purposes, AI is used to reproduce complex human biomechanics in detail to craft simulations as a quick and cost-effective (80 percent cost reduction) way to assess the risks of collisions involving cobots.

Tailored Powder Blends with Low Environmental Footprint for Sustainable Metal Additive Manufacturing — SUSMET, an ICON project of the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM and the University of Waterloo, in Canada, started in November 2023. The collaboration focuses on validation of water-atomized powder for industrially relevant additive manufacturing technologies. SUSMET addresses sustainability (availability of raw materials and carbon footprint) and cost efficiency (approximately one-tenth of present-day powder costs) as well as the digital transformation through sintering simulations.

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, which can last several months, encourage the exchange of knowledge. A new call for applications for the program was issued in the spring of 2023. Eleven grants for stays starting from the fourth quarter of 2023 were approved. Innovative countries in northern Europe (France, Sweden, Norway), the United States, and Australia saw the highest demand. Another round of applications ran until the end of October 2023, this time for stays starting from mid-2024.

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 representative offices provide the Fraunhofer research portfolio with crucial impetus thanks to their knowledge of the respective regional and local research landscape.

The objective of **PACT — Program for Affiliate Cooperation and Knowledge Transfer** and the associated R&D projects, commercialization measures, and initiatives is to create added value for the entire Fraunhofer network by increasing collaboration between the foreign Fraunhofer affiliates and Fraunhofer institutes. In all, 20 PACT projects were launched in 2023, involving 6 foreign Fraunhofer affiliates, 9 centers, and 18 Fraunhofer institutes.

In the **Cultured Meat** PACT project, the Fraunhofer Institute for Molecular Biology and Applied Ecology IME is working with the Fraunhofer USA Center for Manufacturing Innovation CMI over 18 months to transform meat production from an agricultural practice to biotechnological methods using cell cultures. The objective is to produce cultured meat by adjusting existing techniques for cultured animal cells for large-scale use in the food industry.

The **KI4Med — Künstliche Intelligenz in der Medizinischen Bildgebung** (AI4Med — Artificial Intelligence in Medical Imaging) PACT project, which involves the Fraunhofer Austria Center for Data Driven Design (DDD) and the Fraunhofer Institute for Production Technology IPT, aims to develop a medical diagnostic solution based on AI. The objective of the new system is to generate high-resolution contactless and non-invasive tomographic images of tissue and identify changes in the layers of tissue.

The Fraunhofer Institute for Industrial Mathematics ITWM and the Fraunhofer-Chalmers Centre for Industrial Mathematics FCC are working together on a PACT project titled **Efficient Particle Simulation — EFF-PART-SIM** with the aim of simulating the work of agricultural machines on rough and discrete surfaces. The main application lies in the commercial vehicle segment, particularly involving agricultural and construction vehicles.

Fraunhofer international

Business report

Total business volume

In business terms, 2023 was a successful year for Fraunhofer. The total business volume amounted to €3.4 billion, having increased by a substantial 12 percent compared with the previous year. Contract research accounted for 88 percent of this sum (€3.0 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 with long-term funding that falls outside the scope of this regular base funding is allocated to a new item, additional research funding, which amounted to €249 million in the reporting period. Major infrastructure capital expenditure amounted to €164 million. These three segments will be discussed in greater detail in the following sections.
___ *See p. 20, chart titled "Fraunhofer total business volume"*

Business volume is based on the performance statement, which meets the requirements of the grant authorities. 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 2023, Fraunhofer's capital expenditure amounted to €581 million overall, a 17 percent share of the total business volume. Personnel expenses increased by 9 percent to €1,920 million. This is due primarily to a 5 percent increase in permanent staff and to one-time payments to compensate for inflation as part of the collective agreement reached in 2023. At €921 million, non-personnel expenses were 13 percent higher than in the previous year, owing to factors including higher energy and material prices and an increase in externally financed project volume. The reserve was used during 2023 to cover liquidity requirements. €18 million net was released to provide funds to establish high-performance centers, to equip Fraunhofer institutes with solar photovoltaic systems and to fund strategically important formats aimed to promote the acquisition of shareholdings.
___ *See p. 20, chart titled "2023: Total business volume by budget"*

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 2023, the base funding requirement increased by 16 percent to €824 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** rose by 6 percent to a new high of €836 million. While revenue from contracts with industry increased by 8 percent to €679 million, license-fee revenue from industry stood at €157 million, slightly below the high level seen in the previous year.
___ *See p. 20, chart titled "Revenue from contract research"*

Revenue from publicly funded projects increased significantly again in 2023. Project funding from the German federal government, in particular, jumped by 21 percent to €802 million. Within this, the revenue of the BMBF increased by 18 percent to €406 million, the funding of the Federal Ministry for Economic Affairs and Climate Action (BMWK) by 15 percent to €267 million and the revenue of the other federal ministries by 54 percent to €129 million. Project funding provided by the German state governments decreased by 5 percent to €232 million after a sharp increase in preceding years. There was a significant rise in EU revenue, which was up 28 percent to stand at €114 million. Other revenue increased by 46 percent to €183 million and includes funding granted by foundations, universities and other research-funding institutions. In 2023, this figure also includes €19 million in reimbursements under the German Energy Price Brake Act (Energiepreisbremsengesetze) and an extraordinary insurance claim payment of €13 million for the Fraunhofer Institute for Technological Trend Analysis INT based on the flooding in 2021.
___ *See p. 20, chart titled "2023: Revenue from publicly funded projects"*

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 project groups and special effects on the balance sheet regarding reserves and provisions). Due to the significant increase in revenue from publicly funded projects, the project

funding share rose again to 76.4 percent in 2023. The share of funding provided by the German federal and state governments increased to 36.3 percent. At 29.7 percent, the share of industrial revenue was at the same level year over year.
See p. 21, chart titled "Funding share"

Additional research funding

Additional research funding covers research activities with long-term funding outside the scope of regular base funding.

In addition to defense-related research, the National Research Center for Applied Cybersecurity ATHENE and the Fraunhofer Research Institution for Battery Cell Production 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 federal state of Hesse in a ratio of 70:30 and recorded a budget of €24 million in 2023.

With expenses of €84 million, the development of the **FFB** continued to gain momentum in 2023. 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 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 expenses remained at the previous year's level of €141 million in 2023. A small increase of €4 million in the base funding provided by the BMVg brought the total to €87 million, while project funding from the same ministry decreased by €5 million to €54 million.
See p. 21, chart titled "Additional research funding"

Major infrastructure capital expenditure

Major infrastructure capital expenditure comprises building projects and the purchase of scientific instruments and furniture to equip new facilities. At €164 million, investments in **construction and equipping of new facilities** were 13 percent lower than in the previous year, as external influences continued to have a delaying effect on the outflow of spending for construction activities. This includes, in particular, fixed periods from the European Regional Development Fund (ERDF) and increased requirements for funded construction. The amount spent on building projects decreased by €19 million to €133 million, of which €98 million related to major and €35 million to minor building projects. Investments in equipping of new facilities decreased by €6 million to €31 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 €143 million. ERDF funds from the German state governments and other revenue accounted for €21 million of project revenue.
See p. 21, chart titled "Major infrastructure capital expenditure"

Financial and net asset position

At December 31, 2023, the Fraunhofer-Gesellschaft had total assets of €4,855 million, up €239 million or 5 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 62 percent of assets and were €216 million higher at €2,997 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 €195 million to €2,919 million. In addition, shareholdings financed out of reserves were reclassified from current assets to noncurrent assets at the residual carrying amount of €14.5 million at January 1, 2023.

Current assets accounted for 37 percent of assets and were €3 million lower at €1,802 million. Receivables from the German federal and state governments relating to base funding increased by €346 million to €374 million, including

receivables for funding approved during this financial year. Their over-year nature is ensured by the budgetary instrument of Selbstbewirtschaftungsmittel (SBM – resources managed independently). As a result, SBM in the amount of €345,000,000 from the German Federal Ministry of Education and Research (BMBF) and €13,503,000 from the German Federal Ministry of Defence (BMVg) are included (SBM were recognized in cash and cash equivalents the previous year). Receivables from the German federal government and the German state governments from project billing (including contracts) increased by €20 million to €355 million. Receivables from affiliated companies decreased by €7 million to €0.4 million. Cash and cash equivalents (including bank account balances) decreased by €275 million to €18 million. The value of the securities portfolio was €53 million lower, at €459 million. Of this, €372 million stemmed from license-fee revenue reserve, €17 million corresponded to the extraordinary item "For financing restructuring measures" and €70 million was from a patent sale.

Equity — which comprises the non-profit organization capital that is not financed by government grants (€15.6 million) and the reserve for statutory purposes (€11,225) — 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 €216 million higher at €2,986 million. The extraordinary item "License-fee revenue reserve for statutory purposes" decreased by €32 million to €372 million. The "Extraordinary item for payments from patent sales" was €103 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 €17 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. €4.3 million was used for this purpose during this financial year.

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 €320 million at the reporting date.

Provisions increased by €34 million to €277 million, €40 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

€109 million was entered on the assets side of the balance sheet.

Liabilities rose by €106 million to €756 million. In addition to an increase of €77 million in unappropriated grants from federal and state governments from base funding and project billing, trade payables, liabilities from affiliated companies and other liabilities also rose by a total of €29 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 grant authorities 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.

The **Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation)**, established in 2008, is a legally independent institution that supports technology-oriented research projects at the Fraunhofer institutes as per the Statutes. The foundation added €3.7 million in all to the spending capital in 2023. These additions result from donation income, proportionate returns from successful foundation projects, repayable grants, and revenue from asset management. The Fraunhofer Future Foundation provided €6.8 million in funding for projects at Fraunhofer institutes in 2023. This reduced the spending capital from €91.5 million to €88.4 million.

Shareholdings and spin-offs

At the reporting date, the Fraunhofer-Gesellschaft held equity investments in a total of **83 companies** operating in a diverse range of sectors. The **transfer of technology** to industry formed the focus of activities at 53 of the companies in the investment portfolio, while a further 24 equity investments were of a strategic nature. Equity investments also include 6 affiliated companies. In 2023, the Fraunhofer-Gesellschaft invested a total of €7.1 million in the acquisition of equity interests in shareholdings and divested its shares in 6 companies. The Fraunhofer-Gesellschaft added one company to its investment portfolio. Furthermore, 6 others that had previously been held as current marketable securities were reclassified to noncurrent assets. The total carrying amount of shareholdings (including shares in affiliated companies) increased to €31.5 million (previous year: €9.2 million). The significant increase in the carrying amount was driven primarily by the reclassification of the 6 companies from current assets, as their carrying amount at the end of 2023 was €21.8 million. Income from the divestiture of shareholdings came to €7.1 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 2023, Fraunhofer Venture provided support to 71 new spin-off projects; 23 new spin-offs were established. Fraunhofer has set itself the goal of increasing not only the number of spin-offs but also their proportional contribution to overall industrial revenue. Fraunhofer's innovation hub AHEAD offers a package of targeted measures and programs to help achieve this.

Exploitation of intellectual property rights

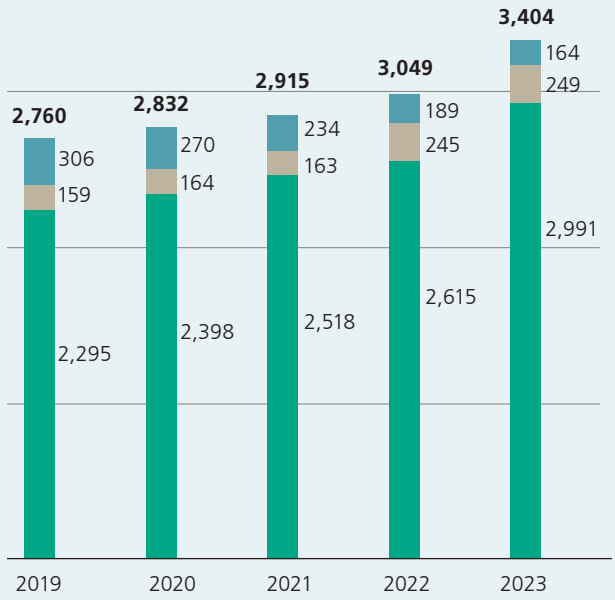
The Fraunhofer-Gesellschaft remains the leader among German research institutions in terms of its annual number of invention disclosures and new patent applications. After the decrease seen in the previous two years, the number of invention disclosures rose again in 2023 to stand at **506 inventions**. The number of **patent applications claiming rights of priority** was also up year over year, at **406**. The lower number of new applications in 2021 and 2022 is having a delayed effect on IP inventory. The Fraunhofer portfolio of active patent families, each of which comprises all intellectual property rights in different countries, decreased year on year to stand at 7,068. General price increases have also caused the institutes to focus even more on the cost aspect of intellectual property rights, so they are clearing their portfolios of older IP rights in some cases. The general strategy of the Fraunhofer institutes remains to secure only valuable inventions permanently under patent law. To guarantee ongoing exploitation of intellectual property rights, Fraunhofer is continuing its efforts to group patents into portfolios that are then offered to selected companies, licensed or, in some cases, sold.

See p. 21, chart titled "Patent applications claiming rights of priority"

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 2023, Fraunhofer concluded 212 new IP licensing or sale agreements, bringing the total number of active agreements at the end of 2023 to 2,989. Revenue from the licensing and sale of IP amounted to approximately €158 million.

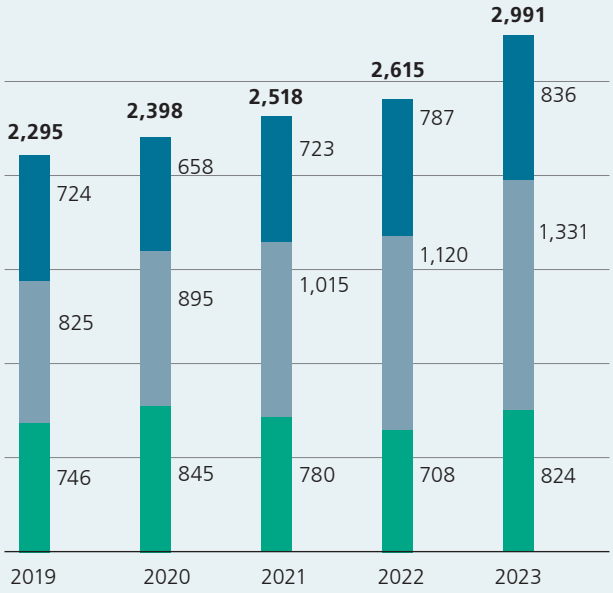
Facts and figures

Fraunhofer total business volume in € million



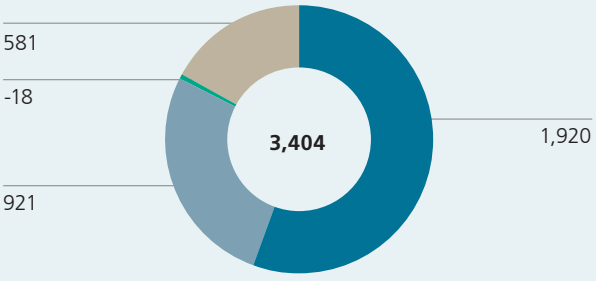
- Major infrastructure capital expenditure
- Additional research funding
- Contract research

Revenue from contract research in € million



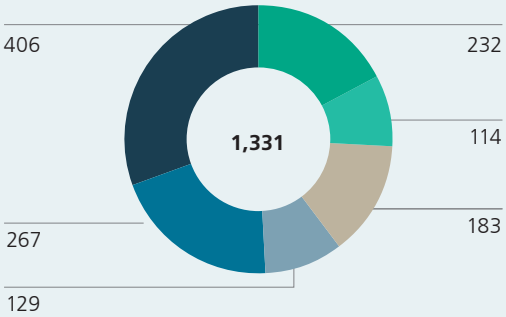
- Industrial revenue
- Revenue from publicly-funded projects
- Base funding

2023: Total business volume by budget in € million



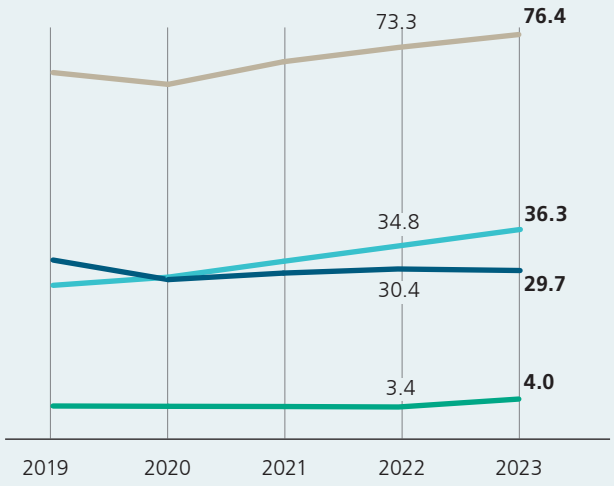
- Personnel expenses
- Non-personnel expenses
- Change in reserves
- Capital expenditure

2023: Revenue from publicly funded projects in € million



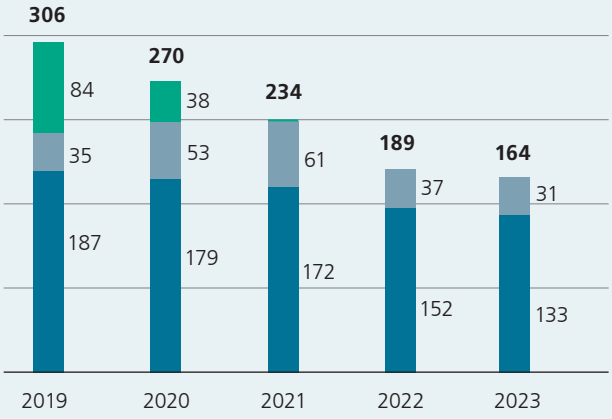
- BMBF
- BMWK
- Other federal ministries
- Federal states
- EU
- Other

Funding share in %



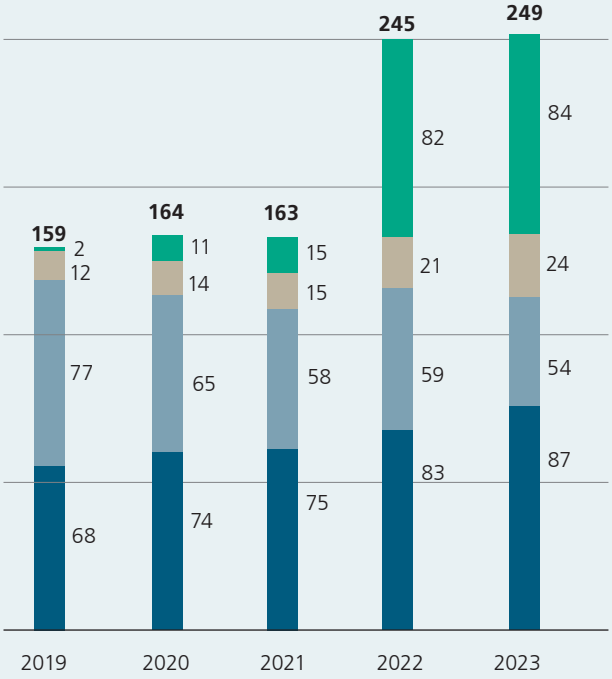
- Total project revenue (including other revenue, 2023: 6.4%)
- Industry
- Federal and state governments
- EU

Major infrastructure capital expenditure in € million



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

Additional research funding in € million



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

Patent applications claiming rights of priority

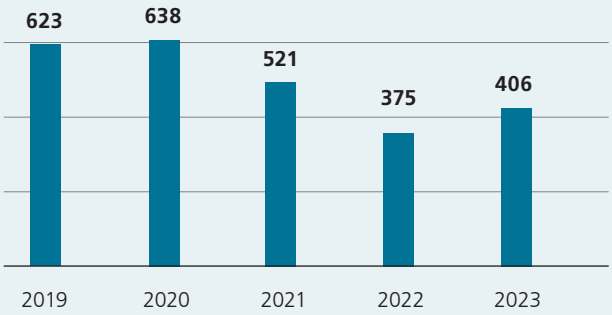


Photo: iStock

Sustainability aspects

Responsibilities of the Fraunhofer-Gesellschaft

For Fraunhofer, sustainability means taking full responsibility for a future worth living in. In addition to research, this encompasses responsible corporate governance as it relates to the dimensions of the environment, the economy, and social matters. Responsibility is also manifested in the ways we give back, including a wide array of development opportunities for employees, efforts to include our communities in research processes, and programs for students at the secondary school and university levels.

Fraunhofer published a detailed corporate social responsibility (CSR) report in 2023. A cross-departmental management structure was established in late 2022 to handle all aspects of sustainability and corporate social responsibility. The focus in 2023 was on compliance requirements and on governance in the area of sustainability. Initial action fields and measures for the strategy that is to be established were defined in the 2023 sustainability report and are being tracked with an eye to quality assurance. For example, efforts to transfer research findings to industry and society are being ramped up through initiatives such as strategic partnerships with industry customers, and cross-organizational dialogue is being established through jointly defined research processes, including those focusing on socially responsible research. Beyond that, efforts to increase women's representation among scientific staff and on institute advisory boards are also under way. Fraunhofer is preparing to provide information **according to the detailed specifications of the Corporate Sustainability Reporting Directive (CSRD)** in the management report **starting in the 2025 financial year**. The CSRD ensures transparent communication and comparability across the sustainability activities of companies and organizations. Fraunhofer is acting early in establishing the necessary processes for collecting data across all units, which is a key prerequisite for accurate, credible, and effective reporting. A central working group appointed by the executive board is hard at work creating the conditions for detailed CSRD reporting that is geared toward material aspects. The double materiality analysis initiated in 2023 will serve as a basis for this. Sustainability-related aspects are considered "material" if they are relevant from either the inside-out perspective (impact of Fraunhofer's business activities on the environment and society) or the outside-in perspective (relevant opportunities and risks that sustainability topics entail with an eye to the future viability of the Fraunhofer business model). A survey of stakeholders on these topics is planned for the first half of 2024.

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 has been continually developed since then in order to comply with increased regulations in the field of research.

At Fraunhofer, compliance is seen 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. 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 compliance control concept, topic owners in the specialist departments regularly review regulatory and procedural requirements (e.g., compliance with inspections).

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 the important tasks: research and the transfer of innovation.

Implementing the German Supply Chain Act (Lieferkettensorgfaltspflichtengesetz, LkSG)

The German Act on Corporate Due Diligence Obligations in Supply Chains (Lieferkettensorgfaltspflichtengesetz, LkSG) entered into force on January 1, 2023. This German federal law governs the economic activities of companies based in Germany with 3,000 or more employees working there (1,000 or more starting next year) by imposing due diligence obligations intended to minimize human rights and environmental risks in the supply chains of these enterprises. The Fraunhofer-Gesellschaft meets the requirements of the LkSG and has taken steps to fulfill its due diligence obligations.

The role of human rights officer falls within a newly created department tasked with monitoring the risks related to human rights and the environment within Fraunhofer's own value chain and supply chain. The **existing risk management system** of the Fraunhofer-Gesellschaft **has been expanded to include the LkSG** and will continue to grow in order to permit identification of risks related to human rights and the environment.

The first regular risk analysis aimed at identifying risks related to human rights and the environment in Fraunhofer's sphere of business and among direct suppliers was performed this year. An external provider that specializes in these matters was brought in to analyze the risks relating to direct suppliers. As the first step, the specifications of the LkSG and the guidelines from the German Federal Office for Economic Affairs and Export Control (BAFA) were used to perform an abstract risk analysis. The results were then subjected to a manual plausibility check. This process identified risks but no violations, and appropriate preventive measures were initiated. Corrective processes that will apply in the event that any violations are identified in the future were also defined.

The Fraunhofer-Gesellschaft human rights strategy was adopted in late 2022. It was set out in a declaration of principles by the executive board and made accessible on the Fraunhofer website as of January 1, 2023.

An LkSG channel was added to the Fraunhofer whistleblowing system to ensure that incoming reports of potential violations can be processed systematically and anonymously.

In relation to indirect suppliers, a process of as-needed risk analysis was defined to allow for immediate action if any violations in the supply chain come to light. The documentation and public reporting pursuant to the specifications of the BAFA will be presented on time as of April 30, 2024.

Sustainability research

Some 32,000 Fraunhofer employees work with partners from industry and the research sector to translate ideas into innovative solutions. These activities are aimed at addressing the urgent challenges facing society today. Fraunhofer's research currently focuses on five overall societal objectives: digitalized value creation, a fully circular economy, completing the energy transition, affordable healthcare, and security and a resilient society. Transferring research findings into application can be a significant help to companies in achieving their sustainability goals and developing more sustainable products and services.

Protecting the climate is one of the most important tasks that our society faces at a global level, particularly when it comes to making the switch to renewable sources in our energy systems and decarbonizing our industry sector. Fraunhofer researchers are making vital contributions to this process. One example is Fraunhofer's **Electrocaloric heat pumps ElKaWe** flagship project, in which teams of researchers are developing electrocaloric heat pumps as an alternative to the currently prevailing compressor technology, which is not cost-effective. These innovative heat pumps promise higher efficiency, plus they operate without any coolant. 2023 saw a milestone in the gallium nitride-based power electronics needed to this end: Fraunhofer researchers finalized an ultra-efficient **circuit topology for voltage converters with 99.74 percent electrical efficiency**. This result is setting standards worldwide and represents an important advance toward zero-emissions solutions for heating and cooling.

The **ReSoURCE** EU project (Horizon Europe) is also making a crucial contribution to cutting carbon emissions. Fraunhofer researchers are participating in the industry-led consortium, where they are working with others on sustainable solutions for recycling refractory materials. The Fraunhofer Institute for Laser Technology ILT and its spin-off Laser Analytical Systems & Automation GmbH (LSA) are involved in these efforts. In particular, they are contributing their laser expertise toward measurement equipment for automated sorting facilities. Worldwide, some 32 million metric tons of used refractory materials are generated each year. Thus far, only a fraction of that amount has been recycled. Producing refractory materials from primary raw materials generates significant volumes of CO_2, so the project's goal is to recycle these materials instead. The researchers' findings will lay the groundwork for increasing the share of these materials that is recycled, which currently stands at 7 to 30 percent, to 90 percent, thereby reducing European CO_2 emissions by as much as 800,000 metric tons per year.

Global water use has nearly sextupled in the past 100 years and is rising by about 1 percent a year. Increasing consumption and pollution of water resources, a growing global population, and longer periods of drought have combined to make

usable water an increasingly scarce commodity. On top of that, approximately 70 percent of potable water is currently used in agriculture, and 60 percent of that is wasted due to over-irrigation. The Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI and the Fraunhofer Institute for Applied Optics and Precision Engineering IOF, in tandem with spin-offs constellr GmbH and SPACEOPTIX GmbH, developed an innovative infrared camera called LisR, short for **"Long-wave infrared sensing demonstratoR,"** to enable greater sustainability in irrigation. LisR measures real-time land surface temperatures from orbit, making it significantly more accurate for irrigation strategies than previously existing models. The technology demonstrator was successfully tested on the ISS International Space Station in 2022. Starting in 2026, this kind of targeted irrigation could save some 180 billion metric tons of water and cut CO_2 emissions by 94 million metric tons — while also boosting global harvests by as much as 4 percent (see 2022 annual report).

One example of sustainability in transferring research findings directly to industry is the **strategic cooperation between Fraunhofer and Procter & Gamble (P&G)**. A new integrated approach was added in July 2023 in the form of the **Joint Innovation Platform**. The platform's objective is to intensify the connections between interdisciplinary Fraunhofer expertise and P&G in order to focus efforts toward sustainability in the supply chain. The long-term strategic partnership is founded on clearly defined goals within P&G's sustainability agenda. Specific P&G pledges include achieving net zero GHG (greenhouse gases) at its more than 200 production sites, distribution centers, and technical centers and in its over 100,000 inbound and outbound transportation routes. The company's goals also include protecting the affected watersheds at all its production sites and reducing use of fresh water by more than 111 billion liters per year. P&G is also working to build sustainability data systems for the supply chain and to provide verifiable, granular, and accessible data for internal and external reporting purposes. The new form of cooperation via the Joint Innovation Platform is intended to lead to efficient, significantly accelerated access to Fraunhofer expertise across four strategic fields: transportation; scope 1 and scope 2 emissions; water; and environmental, social, and governance (ESG) data.

The Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) runs a funding program aligned with the UN's Sustainable Development Goals (SDGs). With an annual funding volume of €5 million, it enables researchers from the Fraunhofer-Gesellschaft to develop products, services, and business models that help to make the world more environmentally friendly, socially equitable and financially viable. In 2023, for example, the foundation provided funding for **NexusHub,** a water-saving system to grow plants in arid regions, and **Phosphatfänger ("phosphate catcher"),** a technological solution developed to reclaim phosphate from wastewater. In implementing its projects, the foundation is increasingly utilizing participatory elements to incorporate stakeholder needs into product development and technology transfer at an early stage.

Transfers of knowledge and technology contribute to Germany's sustainability as a hub of economic activity and help to make society more sustainable through spin-off and licensing projects. In the AHEAD funding program, which supports technology transfers involving innovative ideas, a new line called the **AHEAD SDG Track** was created specifically for spin-off and licensing projects that are important to achieving the SDGs. Participating teams are coached by experts on topics such as impact calculation, the circular economy, and preparing for financing opportunities. The teams' business model is geared toward achieving positive social or ecological impact through their innovative solutions. Since the program was first launched in 2019, 64 teams have completed the SDG Track of the AHEAD program.

The Fraunhofer experts contribute their system expertise relating to future technologies to political decision-making processes. These contributions are in demand in forums such as the **German chancellor's Alliance for Transformation**. In this dialogue format, the German federal government consults with entities representing business and industry, social partners, and the research sector on how to make the social and ecological transformation of Germany a success. Prof. Holger Hanselka attended various meetings in 2023. The federal chancellery appointed Prof. Manfred Renner to the **circular economy task force** within the alliance. Renner is one of the heads of the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT, a role in which he coordinates numerous consortia and activities relating to the circular economy.

He contributed significant expertise on circular value creation in batteries and circular management in relation to construction, building materials, and buildings to a position paper published by the task force.

Socially responsible research

The initiative for socially responsible research describes researchers' holistic responsibility for the various aspects of their activities. At the corporate level, this includes questions on the choice of research topics (What should we research? What do we not want to research?), and at the level of individual R&D projects, it involves carrying out projects with quality assurance and transferring the results with a focus on benefits. Based on an established framework for reflection (LeNa joint research project of the German Federal Ministry of Education and Research together with the Leibniz Association

and the Helmholtz Association), internal and external areas of responsibility for Fraunhofer project teams were defined as part of a further Fraunhofer project in 2023. These areas can now be discussed based on new guidelines. The internal area of responsibility addresses the design of the research process, and especially good scientific practice, quality assurance for project management, and — where necessary — adherence to codes of ethics during project implementation. External responsibility toward stakeholders includes grappling with the potential ramifications of project results, both through the necessary transfer of results to deliver benefits across industry and society and through a capably performed impact assessment to minimize the risks of misuse and abuse of research findings. The guidelines are intended to assure Fraunhofer project teams that all of the relevant aspects relating to responsibility have been taken into account through open internal discussion as a group before a project starts. In particular, scientists are invited to contribute their own individual moral views, and raising awareness of ethical issues, especially new ones, is a focus of the process. The guidelines were introduced on an optional basis for all Fraunhofer project teams, along with a module for Fraunhofer's central continuing education activities titled **Introduction to the Ethics of Technology and Technology Impact Assessments** (launching in 2024). Both measures — the guidelines and the module — serve to strengthen excellence in Fraunhofer research and foster people's greater satisfaction with their own work.

Community participation in the research and innovation process makes an important contribution to shaping innovation for maximum benefit. In an EU project titled **FRANCIS — Frugal Innovation by Citizens for Citizens** (funding period: 2021–2024), the Fraunhofer Institute for Industrial Engineering IAO and the Fraunhofer Information Center for Planning and Building IRB joined with further partners to kick off a series of so-called open innovation challenges open innovation challenges. The challenges invite people all over the world to develop ideas for simple, sustainable solutions. The project puts special effort into motivating and empowering marginalized groups, such as older people, to participate. The first idea competition, which covered the topic of the culinary world and home care and was aimed primarily at three countries — Germany, Turkey, and India — was concluded in August 2023. The top three placements went to a personalized furniture concept, a bed-making device, and a clever recycling system.

Sustainability management at non-university research organizations (PDF only available in German)

Employees

At year-end 2023, Fraunhofer had 31,942 employees, 23,543 of whom were research, technical or administrative staff (RTA staff), 7,887 were students and 512 were trainees.

The goal of **knowledge transfer via individuals** is for excellently trained Fraunhofer employees to take on positions of responsibility in industry or the research sector or to start their own businesses after a few years.

Fraunhofer added 1,113 people in scientific, technical and administrative roles in 2023. In fact, 3,300 people were newly brought on board, while 2,200 left the organization. This turnover is intentional, and especially amid today's shortage of skilled workers, it requires professional recruitment and onboarding, structured career support, and high levels of leadership and management skills.

Since autumn 2022, the **Fraunhofer Corporate Culture Vision of the Future** project has been working on an analysis of current framework conditions and on levers to develop the Fraunhofer culture even further. This is to establish processes and structures that promote ongoing cultural dialogue. Two closely coordinated participatory dialogue formats were implemented starting in late August 2023:

- Meet the Executive Board
  This open discussion format centering on current overall conditions and future prospects is based on personal discussion between employees and at least two executive board members. It is a way for the executive board to address internal and external dynamics at the Fraunhofer-Gesellschaft by meeting people where they are, taking note of their needs, and giving employees as a broad group an opportunity to share their personal experiences and wishes with the board. A total of 7 workshops were held, one each at 7 different Fraunhofer locations.

- Cultural Dialogue
  Fraunhofer employees met for 16 target group-specific workshops where they mapped out positive changes they would like to see in Fraunhofer's culture going forward. Representatives from each Cultural Dialogue will discuss their findings with the executive board afterward and synthesize them into a vision of the Fraunhofer corporate culture of the future.

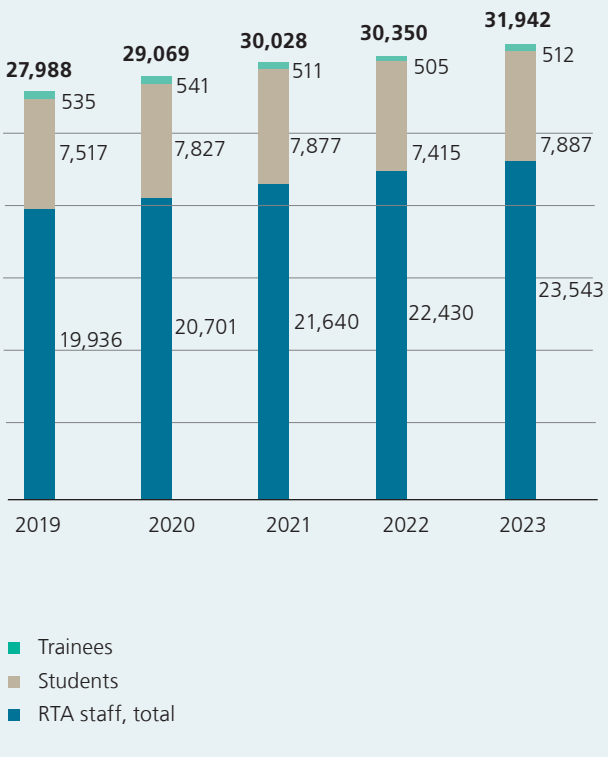
With the dialogue events concluded, the final phase of the project involves developing and establishing tools and formats to support the continuation of cultural dialogue and feedback and consequently the evolution and further development of the culture.

One major area of focus in 2023 was the **introduction of a new employer brand** with a new slogan, **"Change starts with us,"** which replaced the previous "YES" campaign. The new brand provides the overarching structure for all of the institutes' communications aimed at a broad range of different target groups, shows team spirit and diversity, and offers authentic insight into Fraunhofer by spotlighting real employees in their own work environments.

Further development of overall working conditions

One of the main ways that knowledge transfer via individuals, a key mission for Fraunhofer, is implemented is the **careers with Fraunhofer** approach, which is based on a holistic personnel development concept geared toward supporting employees' individual career planning. Mandatory **employee development meetings** constitute the key element of individual development planning. Individual career planning processes are based on Fraunhofer's development and career paths (both internally and with regard to conventional next-step careers in industry, academia or spin-offs), which are consolidated through defined qualification fields, topics and measures. Now that the **SuccessFactors Talent** SAP tool has been introduced Fraunhofer-wide as a standardized platform providing digital support for development planning and the SAP learning management system is in place as a uniform learning platform, extensive efforts have gone into expanding the range of e-learning courses available. There are now about 50 free e-learning courses on topics such as leadership, business management, and work and self-organization that all employees can access for self-paced continuing education purposes. In addition, **target group-specific career programs** continue to assist employees in networking across institute boundaries: the **Vintage Class** and **Advanced Management Class** for top-level and upper management staff, **TALENTA** for female scientists and scientific managers, and the **Step forward** program for young professionals. A new **business management program** has also been added to optimize exploitation, business development, and cooperation with industry customers at the institutes.

Employees (number at year-end)



The **"A Doctorate at Fraunhofer" Code of Conduct, which was adopted in 2020,** sets binding quality standards for the overall conditions of doctoral supervision at Fraunhofer. A detailed survey was conducted in May 2023 to evaluate the degree to which the quality standards outlined in the code of conduct are currently being implemented at the institutes. Institute directors, supervisors at the institutes, and doctoral candidates employed by Fraunhofer were all asked for their opinions and evaluations. This descriptive snapshot of the situation at Fraunhofer shows the various strengths and weaknesses on the subject of doctorates with Fraunhofer. A correlation analysis was also performed, identifying a range of correlations between contextual factors, aspects of doctoral supervision, and performance indicators (job satisfaction, progress toward the doctorate, duration of doctorate, non-completion rate, attractiveness as an employer). There were two key takeaways from the survey. First, the quality standards set down in the code of conduct make a crucial contribution to the performance indicators, and second, there are important areas of leverage that have now been identified and can be used in crafting specific plans of action.

The systematic **exit survey** of employees leaving Fraunhofer is an important instrument for identifying the effectiveness of the measures within the overall HR development strategy. There was a positive shift in 2023 on the key question of whether departing employees would recommend Fraunhofer as an employer. The approval ratings are currently at 63 percent (up from 60 percent in 2021 and 59 percent in 2020). A consolidated development status is apparent in the voluntary quit rate, which stands at 75 percent in 2023 (up from 74 percent in 2021 and 73 percent in 2020) In keeping with the Fraunhofer approach, "knowledge transfer via individuals" was the most frequent reason cited by those leaving the

organization at their own request, at 26 percent (compared to 49 percent in 2021 and 27 percent in 2020). Positive ratings for support with development planning among departing employees stood at 51 percent in 2023. That represents a significant increase from previous years (40 percent in both 2021 and 2020). This positive trend was apparent across all groups of employees during this reporting year.

These working conditions are one of the reasons that Fraunhofer is ranked in the **top employers** list every year. In 2023, the Fraunhofer-Gesellschaft was also one of the most popular employers in the Trendence and Universum employer rankings. Fraunhofer placed first in the Trendence barometer of graduates in the research category and second, also in the research category, in the professional rankings.

Diversity

Achieving innovative strength through scientific excellence is a core part of the mission of the Fraunhofer-Gesellschaft. With that in mind, Fraunhofer's objective is to foster a research and working environment in which all employees experience equal opportunity as a result of the support provided for diversity and the creation of overall conditions of inclusivity. A comprehensive approach to diversity management supports a cultural shift toward equal career opportunities for women and men, appreciation for the diversity of all employees, and development of inclusive overall conditions. In this regard, grant initiatives at Fraunhofer are congruent with the objectives of the Pact for Research and Innovation and with the **Gender Equality Plan** implemented by the European Commission in 2022.

Equal opportunities in the workplace are central to the overall approach to diversity. A holistic concept strengthens the ambitious goals of gender equality. To bring about **equal opportunity and family-friendly structures and processes**, Fraunhofer has embraced an overall plan that systematically combines six fields of action: recruitment, career progression, communication, cultural transformation, monitoring and general conditions. The **equal opportunities support program** was continued in 2023 as a centerpiece of these efforts. The program supports the institutes in developing a strategy, analyzing the status quo, and identifying actions to take to promote equal opportunity.

TALENTA, launched in 2013, is a key component of equal opportunity in research and leadership positions. The support and development program transitioned from project start-up financing to a permanent funding model in 2023. In this time, 812 female researchers at Fraunhofer have been able to take advantage of the program, which includes support for career and research time alongside qualification and networking formats to achieve their career goals, such as completing their doctorate, further developing their leadership skills or strengthening their scientific visibility.

Fair career opportunities are heavily influenced by unconscious bias. The **Unconscious Bias pilot initiative** was launched in 2023 to help institutes introduce measures to counter bias. Nine institutes utilized the analysis, training, and communication package developed toward this end in 2023.

For the past 12 years, the **Diversity funding program** has been assisting institutes in implementing new measures to promote equal opportunity and diversity. Since then, a total of 240 applications from institutes have been funded at a total cost of €2.3 million. The institute-specific initiatives funded in 2023 include strategies for raising awareness about diversity, predominantly focusing on unconscious bias, innovative accessibility measures for people with disabilities and workshops to promote intercultural collaboration.

In October 2023, the Fraunhofer-wide framework agreement with **pme Familienservice** (emergency childcare, home care and eldercare, and life coaching) was extended for two years. Since then, the use of the pme Akademie, which includes webinars, e-learning programs and suggestions for living mindfully, has also been included. In 2023, in addition to 9 cases where childcare was used and 70 requests for home care and eldercare, life coaching was used most frequently, with 130 requests.

The **FamilienLOGO** certification process, which Fraunhofer supports, serves to review the status of work-life balance within an institute through dialogue between the institute management or administration and the equal opportunities officer. The certification process focuses on the following aspects: information and communication, flexible working arrangements, institute-specific care options, parental leave and returning to work, Fraunhofer support options, and budget for work-life balance. In 2023, 6 institutes took advantage of the opportunity to obtain the certification for the first time. Of those institutes, 4 were granted the Familien-LOGO for their outstanding family-friendly conditions. In all, 24 units have received the FamilienLOGO since 2019.

Fraunhofer is committed to equal opportunity and inclusive conditions for all employees. At Fraunhofer, inclusion means that people with and without disabilities can work together and conduct research naturally and on equal terms. Our primary goal is to design working conditions, structures and processes that fulfill the needs of all employees, with or without disabilities, while also promoting diversity awareness within the organizational culture in the long term. An analysis of the current situation and any gaps was performed in 2023 with an eye to crafting an **overall plan to promote inclusion**. Particular room for improvement was identified in the areas of accessibility, raising awareness and skill building, and fighting bias. An initial package of strategic measures was put together on this basis. To raise awareness of equal rights for people with disabilities in science and the research sector and foster inclusion, the Fraunhofer-Gesellschaft and Max Planck Society teamed up to launch the Inclusion Initiative. It is supported by all 10 members of the German Alliance of Science Organisations. The initiative mainly comprises:

- **Strategy workshop in November 2023**
  Approaches for encouraging inclusion in science and research were devised, and a roadmap of actions for 2024 was drawn up.

- **Career event in December 2023**
  More than 100 external candidates with disabilities learned about career paths at research organizations.

- **Social media campaign from November 2023 to January 2024**
  The campaign showcased snapshots of the strategy workshop, the career event, innovative research projects and inspiring career paths pursued by people with disabilities.

Sustainability in scientific research

Climate-friendly research processes and infrastructures are a key sustainability goal for Fraunhofer, which is why Fraunhofer takes concrete action to reduce greenhouse gas emissions as part of its **own climate strategy**. Increasing energy efficiency is a crucial element of these efforts. **Energy management systems** have been introduced at multiple institutes, and there are plans to implement an ISO 50001-certified energy management system across the entire organization. Cross-institute energy efficiency and climate action networks have also been initiated. In 4 regional networks, which were each set up for a 3-year period, 50 institutes are supporting the monitoring of specific targets for reducing environmental impact. The networks also connect members with support from moderators, presenters and external energy consultants. An **internal funding program** was created in mid-2023 with €20 million in initial funding for necessary investments in energy efficiency and climate action measures. Applications for the program reached some €2.1 million in the first 6 months.

Purchases of **green electricity starting in 2023** allowed Fraunhofer to lower emissions across the organization by an estimated nearly 35,000 metric tons of CO_2 equivalents (CO_2e) compared to the previous year. This value was extrapolated based on the available figures for total electricity use for 2021. In the heat sector, use of **geothermal systems** is one way to help reduce CO_2 emissions. In 2023, 2 climate action projects on near-surface and medium-deep geothermal systems were launched to assess selected Fraunhofer locations in order to determine feasibility and options for usage as well as support them during the implementation phase.

Efforts to expand self-sufficiency in energy sourcing are also advancing through **solar arrays**. Of these arrays, 64 were approved across Fraunhofer as of the end of 2023, when the internal photovoltaic (PV) program concluded. The average application volume came to approximately €0.4 million each. In total, €25.0 million was approved, and the planned capacity amounts to 12.03 MWp. The amount of electricity generated would be sufficient to supply approximately 2,600 four-person households with electricity. About five percent of Fraunhofer's total electricity consumption can thus be covered by these PV systems.

Number of solar arrays	64
Average application	€ 0.4 million
Funding volume	€ 25.0 million
Installed power	12.03 MWp
Expected power generation	12,181 MWh

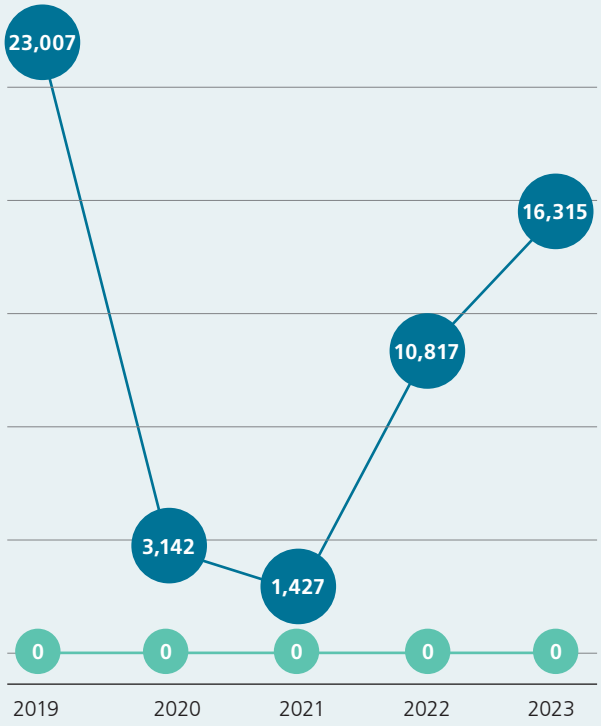
The funds for developing these solar arrays were provided to the institutes through an interest-free internal program aimed at swiftly ramping up in-house power generation through solar solutions. The institutes benefit from energy savings, as a full return on the cost of purchasing the photovoltaic system typically materializes within the space of 10 years. While PV systems do not release any CO_2 during operation, a holistic view must also take into account production (upstream chains) and disposal of the system. The German Environment Agency (UBA) puts the greenhouse gas potential for solar power at 56 g CO_2e/kWh when the system is operated in Germany. The emission factor for the electricity mix in Germany, with upstream chains taken into account, is approximately 485 g CO_2e/kWh in 2021. In addition to the beneficial economic component, solar expansion is also highly important to the Fraunhofer climate strategy.

2023 brought another significant **increase in business travel**. Business travelers logged 9.3 million more passenger kilometers traveled by train than in 2022, for a total of 27.5 million passenger kilometers. That is approximately 75 percent of the figure for 2019, before the coronavirus pandemic. By using the framework agreement between the German federal government and Deutsche Bahn, train journeys for Fraunhofer continue to be regarded as carbon-neutral. Air travel also noticeably increased, rising 50 percent year over year. That brought the CO_2e total for 2023 to exactly 16.315 metric tons (data and calculation by AirPlus/atmosfair).* This represents 71 percent of the emissions for 2019. Emissions from flights taken in 2022 were neutralized in 2023 via a biogas project in Nepal conducted with atmosfair. Plans also call for emissions from flights taken in 2023 to be offset.

Total waste figures are available with one year's delay, so they are currently only available for 2022. According to these figures, the Fraunhofer institutes generated 5,349 metric tons of non-hazardous waste and just under 579 metric tons of hazardous waste in 2022. Fraunhofer distinguishes between hazardous and non-hazardous waste in keeping with the German Waste Classification Ordinance (Abfallverzeichnisverordnung, AVV). This works out to another slight decrease in non-hazardous waste and a decrease of more than 100 metric tons in hazardous waste compared to 2021. Many institutes maintain leasing arrangements in which traditional non-hazardous municipal waste (paper, residual waste, plastics, etc.) is disposed of in part by the landlord or, in the case of collaborations, by higher education institution partners. Rough estimates are prepared for these cases. The data transmitted do not cover all Fraunhofer research units and institutes. 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.

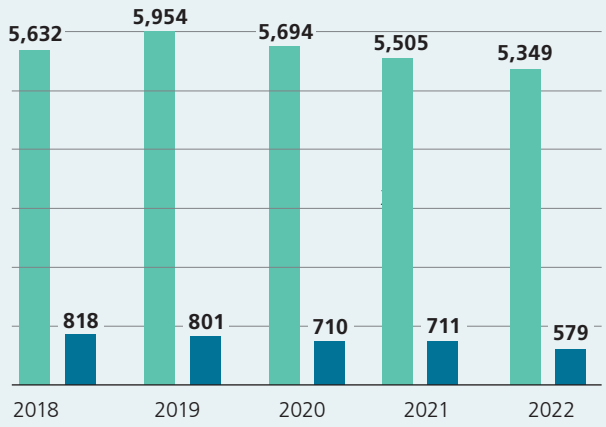
* Since the decision to offset air travel in 2019, flight-related emissions have been calculated using the VDR standard with a Radiative Forcing Index (RFI) of 2.7 in order to take into account the total climate impact of flights taken by Fraunhofer employees. In the interests of transparency, these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

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 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

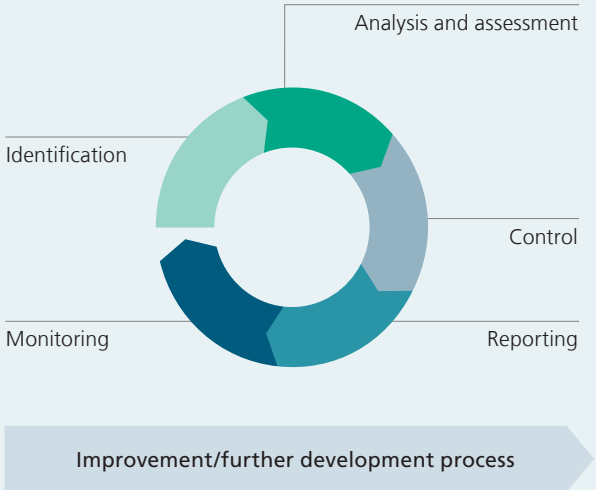
Risks and outlook

Risk management and risks

An overall assessment of the risk situation at the Fraunhofer-Gesellschaft continues to show potential risks similar to those faced by many other institutions and companies. These risks stem mainly from the ongoing and multifaceted crisis situation, which includes geopolitical tensions, price increases, and a dim economic outlook. One additional factor affecting Fraunhofer specifically is that trust remains to be rebuilt among stakeholders, cooperation partners, and the public in the wake of the reports issued by the German Court of Audit (BRH) and amid the ongoing audits. Steps to address these factors through adjustments in governance and to increase efficiency in business processes were initiated at the end of 2023. At present, however, there is no sustained risk to the Fraunhofer-Gesellschaft in the next year.

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 statutes. To achieve this objective, the Fraunhofer-Gesellschaft has set up a risk management system that takes into account its requirements and structure and undergoes continuous improvement. In the cyclic risk management process, risk experts in the specialist departments carry out systematic, standardized risk assessments on a yearly basis. Overarching high-level risk surveys of upper management are also conducted to supplement these efforts. In these surveys, managers identify what they believe to be the biggest risks to the Fraunhofer-Gesellschaft, regardless of the specific topics for which they are responsible, and propose actions to take to mitigate those risks. This information is used along with external risk assessments to review whether the information is complete and perform plausibility checks. The individual risks identified through the standardized risk inventory process and the associated countermeasures are then summarized and evaluated collectively under the appropriate risk categories in an annual risk report that is presented to the executive board. Additionally, the specialist departments inform the executive board of relevant risk-related developments — both routinely and on an ad-hoc basis — via the established reporting channels.

Cyclic risk management process



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 risks (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 current crises — namely the wars in the Middle East and in Ukraine, supply chain disruptions, high (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 tension with the German federal budget and the **need for budget consolidation**, potential budget cuts by the grant authority or restrictions in budget flexibility may lead to a decrease in public funding. The amount of base funding also creates tension on Fraunhofer's funding, as the **rate of inflation** exceeds the increase in base funding agreed as part of the Pact for Research and Innovation, so there has been a reduction in real terms. In these challenging times, it is essential for the institutes and the research portfolio to be financially sustainable within the Fraunhofer model, including in the long term. The necessary measures are apparent from the consolidation course. The relative share of industrial revenue stands at 29.7 percent, slightly below Fraunhofer's target of about one-third, as revenue from publicly funded projects remained high in 2023. Actions taken to consistently implement Fraunhofer's mission of economic cooperation include optimizing the range of services offered and adjusting the research portfolio. Nevertheless, efforts to increase industrial revenue do depend on the overall economy. The Fraunhofer funding model has proved to be highly resilient in past crisis periods, with the result that the Fraunhofer-Gesellschaft continues to assume it will achieve balance among its sources of funding.

In order to maintain the share of base funding in the funding mix in the long term, Fraunhofer **proactively pursues forward-looking economic management** and promotes **mission-oriented, success-based institutional funding** from the federal and state governments along with **business management conditions appropriate to the research sector**. The current financial statutes enable Fraunhofer to operate in a flexible, efficient and autonomous way. If these options were curtailed, it would limit Fraunhofer's liquidity and safeguards against risks, thereby sharply restricting its flexibility and capacity to respond to new developments.

Projects for **building and equipping new facilities** that are co-financed by the federal and state governments and the EU (ERDF) are subject to restrictions concerning how long the funds are made available. Significant delays in project progress can lead to a delayed outflow of funds or even forfeiture of the funds provided. Fraunhofer has a construction control unit in place to monitor the progress of projects for building and equipping new facilities and to continuously explore possible means of expediting such projects. Strategic measures are also taken with an eye to determining construction volumes and setting priorities. Investments and maintenance of research infrastructures are key factors for Fraunhofer in maintaining its ability to operate successfully in the future.

Resources risk encompasses those types of risk that may affect the availability of tangible and intangible resources needed to successfully carry out research activities. Ongoing macroeconomic and geopolitical uncertainties mean that the Fraunhofer-Gesellschaft has various challenges to contend with. In the energy segment, for example, service interruptions and price increases are risks that cannot be ruled out. The Fraunhofer-Gesellschaft continues to take measures aimed at **enhancing a resilient and sustainable energy supply** and bolstering **general resilience in the face of crisis situations**. Efforts toward efficient design of business processes in research management have been ongoing since 2022. There are still challenges associated with the shift to the SAP S/4HANA system, especially in terms of the throughput times for individual business processes. Measures have been put in place to enhance the efficiency of business processes, such as purchasing processes, and ensure compliance. Work to refine the customized SAP tools used to account for documentation-heavy public projects with highly variable formal requirements is ongoing.

The **reputation** of the Fraunhofer-Gesellschaft and its brand is a valuable asset and forms the basis for long-term collaborations and economic success. Responsible corporate governance is a top priority for Fraunhofer. As a matter of course, this includes compliance with all applicable laws, including the specifications of funding legislation, and with requirements set by customers and cooperation partners. Good scientific practice likewise forms the basis for all research activities undertaken at Fraunhofer. This means the potential for reputational harm resulting from negative media reports and delays in business dealings is a threat that must be taken seriously. Fraunhofer is aware that individual missteps cannot be ruled out entirely and can also tarnish the organization's reputation. To identify risks like these as soon as possible and minimize their impact, Fraunhofer focuses on ongoing **further development of compliance, communication, and brand management** and on **consistent monitoring** (see p. 23, "Sustainability aspects, realignment of the compliance management system").

Business operations risk comprises those types of risk that may arise from research and administration processes, or from conducting specific research projects. Increasingly stringent regulatory requirements pose a challenge for an applied research organization with a very broad industry portfolio. They also tie up capacity needed to shape the future viability of industry and society.

Sustainability is growing more and more important, not only due to the increasing impact of climate change, but also as a result of requirements established by society as a whole, customers, and specific regulations. As a result, efforts toward **holistic coordination of all three dimensions of sustainability** (environmental, social, and governance) undergo further development and integration into the overall strategy and organizational structure. Clear responsibilities, job descriptions, and resources for operational execution of the planned regulatory requirements such as the Corporate Sustainability

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	Human resources
	IP, know-how
	Infrastructure
	Financial assets, reserves
	Reputation, brand
Business operations	Service performance, contractual risks
	Legal risks
	Information security
	Governance, internal control systems

Reporting Directive (CSRD) and Corporate Sustainability Due Diligence Directive (CSDDD) are also defined as part of implementation projects.

Secure handling of information and data is critically important to a knowledge-based research organization. The risk of cyberattacks (ransomware, cyber-espionage) continues to rise in tandem with increasing international conflict. Fraunhofer is addressing this risk in the short term through actions such as **improved data backups** and in the long term by planning for a more secure IT architecture ("zero trust" principles), which is being devised as part of the **executive board project on cybersecurity**. Risks posed by the use of disruptive technologies such as artificial intelligence (AI), especially in its generative forms, and quantum computing are also considerations here.

Outlook

Despite increasing economic challenges, Fraunhofer **remains financially stable** for the 2024 financial year.

Public-sector employees saw a significantly larger pay raise under their collective agreement than in previous years, which will also increase personnel expenses — the single largest block of costs — by a significant margin. The institutes are also planning personnel growth, albeit at a noticeably slower rate than in 2023. Although inflation seems to have peaked, higher procurement costs still need to be financed in the long term. In terms of the **supply of electricity and gas**, Fraunhofer has achieved some certainty on pricing thanks to **framework agreements for 2024**. On the whole, non-personnel expenses are expected to rise only slightly year over year. With investment activity remaining more or less constant, Fraunhofer

expects total business volume to increase by a significantly smaller margin than last year.

On the funding side, Fraunhofer has solid orders for 2024 at this point. The planned revenue increase in publicly funded projects is a near certainty due to a large backlog of orders. The industrial revenue situation remains challenging. Amid growing uncertainty in the overall economic situation, the increase in absolute terms that has been planned by the institutes would be a win. The share of funding from industrial revenue is unlikely to rise significantly given the current situation. It is difficult to foresee at this point how rising geopolitical tensions (the war between Russia and Ukraine, the Middle East conflict) and the risk of a lasting recession in Germany will affect the development of Fraunhofer's business.

At the same time, the **need for transformation in Germany and Europe** is increasing and requires more speed if **international competitiveness and prosperity** are to be maintained in the future. Challenges include the global competition for monopolies on resources and technologies and for skilled workers, a sharp increase in geopolitical conflict, the worsening climate crisis, the destabilization of entire societies through targeted disinformation, cyberattacks, and infrastructure attacks, and last but not least, disruptive changes brought about by generative AI and the platform economies.

With its mission of applied research and accelerated transfer, Fraunhofer has a special role to play in harnessing holistic solutions to help make industry and society more resilient and forging ahead with the digital and sustainable transformation. **Next-generation computers and microchips** hold out special promise for Europe as a whole and Germany specifically. The next big technology cycle will be based on research-intensive technologies such as **quantum and neuromorphic computing (QNC)**. Advances in these fields are being made under the umbrella of the Research Fab Microelectronics Germany (FMD) in tandem with other partners with the goal of ensuring that Germany and Europe not only remain competitive, but also can build access to production sites, for example within the framework of the QNC Space module. A broad technological basis within that module ensures that a wide range of approaches to quantum computing — superconducting, neutral atom, ion traps or quantum dots and other approaches such as memristors for neuromorphic computing — can all be tested. Fraunhofer researchers are involved in a range of activities to develop solutions and methods geared toward making information and communication technology less resource-intensive, such as the **GreenICT@FMD** initiative.

Beyond digital solutions, **sustainability and resource efficiency** are critical considerations for all key technologies right from the start. This includes relying on renewable raw materials, reclaiming and recycling critical materials through a circular economy, and eliminating substances harmful to health and the environment. There is also an increasingly urgent need for strategies and technologies to combat climate change and its effects. Germany in particular and Europe in general have a significant edge in this field, known as **green tech**, thanks in no small measure to Fraunhofer technologies. The task now is to seize the first mover advantage on the international stage and swiftly bring developments and business models to market.

For Fraunhofer's research findings to have an impact as they make their way into industry and society via a diverse range of pathways, it is crucial to establish **overall conditions that are innovation-friendly**. This includes experimental spaces where researchers work shoulder to shoulder with industry under market-driven conditions while EU state aid law, aspects of nonprofit status, and other regulations are also considered — in pursuit of topics such as generative AI solutions to alleviate the shortage of skilled workers.

The "twin transformation" — that is, the simultaneous shift toward digital solutions and sustainability — can only be a success in today's tough environment if it is achieved and implemented faster. The only way to accelerate the pace of change from initial concept to proposed solution will be to ease the burden of bureaucracy and foster greater cooperation between the research sector, business and industry, and government. New business and funding models, such as **the expansion of regulatory sandboxes and new forms of cooperation for shared use of cutting-edge research infrastructure, especially by private-sector companies**, are possible approaches for Fraunhofer.

The executive board would like to thank the members, supporters, friends and, most of all, the employees of the Fraunhofer-Gesellschaft for their support, dedication and hard work in 2023.

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

The executive board
Prof. Holger Hanselka
Elisabeth Ewen
Dr. Sandra Krey
Prof. Axel Müller-Groeling

The senate's report

- The senate s report on the financial year 2023
- New senate members

The senate's report on the financial year 2023

Hildegard Müller, Chair of the senate of the Fraunhofer-Gesellschaft

The main theme of 2023 was change. Amid today's tense economic environment and need for internal change, the Fraunhofer-Gesellschaft faced a variety of challenges, as did many other organizations. Thanks to the active, committed and combined efforts of its nearly 32,000 employees, Fraunhofer was able to maintain a steady course and stay on track toward its objectives. This course includes numerous internal change processes that the senate has been instrumental in initiating and supporting.
This approach is helping to safeguard the Fraunhofer-Gesellschaft's future viability so it can continue to perform its full role as an important partner in ensuring that Germany and Europe as a whole remain an innovative, sustainable, and prosperous hub of economic activity.

The Fraunhofer-Gesellschaft continued on a steady financial course in the financial year 2023, as previously. Total business volume increased by a moderate amount, to €3.4 billion. The contract research area grew to €3.0 billion. Industrial revenue (including licenses) reached a high of €836 million — a trend that is expected to continue going forward as well. Prof. Holger Hanselka, newly elected by the senate in 2023 to serve as the president of the Fraunhofer-Gesellschaft, worked with the executive board and in close coordination with the institutes to realign the entire organization toward the twin aims of expanding and strengthening the role of the Fraunhofer-Gesellschaft, primarily with an eye to values-driven research, and successfully transferring ideas and innovations to the German and European industrial sectors. In the spirit of what makes the Fraunhofer model unique, Fraunhofer is renewing its focus on industrial revenue from contract research and licensing and on spin-offs as well in an effort to transfer Fraunhofer research and development into the market through sustainable and innovative business models. This represents a substantial contribution to the ability to innovate within Germany and throughout Europe.

In its role as an innovation driver, Fraunhofer is especially pivotal in transferring research focused on the digital and sustainable transformation. Starting with the OpenGPT-X initiative for large European language models for use in artificial intelligence (AI), Fraunhofer is involved in value-based generative AI developments. The goal is for future models to offer reliable fact checks, accurate and reliable sourcing, and data control, especially for industrial applications. Further growth opportunities for Europe and Germany lie in next-generation computers and microchips based on quantum and neuromorphic computing (QNC). Participating in shaping technological developments is at the forefront there. An alliance of Fraunhofer and Leibniz institutes is advancing innovation in this area under the umbrella of the Research Fab Microelectronics Germany (FMD). For example, the GreenICT@FMD initiative is exploring ways to reduce resource consumption in the information and communication technology sector.

Photo: Dominik Butzmann

Fraunhofer is especially committed to environmental, social and economic sustainability. The Fraunhofer Hydrogen Network, spanning nearly 40 institutes, is supporting the ramp-up of an industrial sector that uses green hydrogen as an energy source, for example. The H2GO — National Action Plan for Fuel Cell Production project, which is aimed at achieving carbon neutrality in heavy goods transportation — has 19 Fraunhofer institutes involved. And last but not least, the Fraunhofer Research Institution for Battery Cell Production FFB is to begin operating a demonstration line, the FFB PreFab, in 2024.

Researchers from the Fraunhofer institutes provide crucial ideas and contributions for the key challenges of our time. For Fraunhofer employees to be able to do their work effectively, overall rules defining a shared modern culture of compliance are needed. On that basis, the senate, president, and executive board joined forces in the fall of 2023 to launch a governance reform program with the goal of moving the Fraunhofer-Gesellschaft to a contemporary governance structure that accommodates the organization's growth and expansion over time, along with its role within the industrial and research landscape. This reform process ties in with the improvements suggested by the German Federal Court of Auditors, the senate, the grant authority, and the executive board. All of the responsible parties will devote themselves to this outstanding project, which is expected to point the way forward.

In 2023, the senate fulfilled the duties entrusted to it under the statutes. It met five times during the financial year 2023. In addition to regular hybrid meetings on May 25 and October 26, there were three special meetings held digitally on April 28, July 24, and September 1. Key resolutions concerned matters relating to the executive board and the structure of the Fraunhofer-Gesellschaft.

- Prompted by Prof. Reimund Neugebauer's resignation as president, the senate unanimously elected Prof. Holger Hanselka to serve as the new president and Executive Vice President for Corporate Strategy, Research and Communications on the recommendation of a senate committee for the election and re-election of executive vice presidents commissioned for this purpose. Prof. Hanselka took up his position as a member of the executive board and President of the Fraunhofer-Gesellschaft on August 15, 2023. Dr. Sandra Krey, Executive Vice President for Finances and Controlling, led the Fraunhofer-Gesellschaft in the interim.

- At its special meeting on April 28, 2023, the senate resolved to establish a temporary senate committee for executive board matters, which was tasked with monitoring practices within the executive board in connection with the findings of the German Federal Court of Auditors report titled "Selected Aspects of Budgetary and Financial Governance at the Fraunhofer-Gesellschaft" (Ausgewählte Aspekte der Haushalts- und Wirtschaftsführung der Fraunhofer-Gesellschaft) and the associated law enforcement investigations under way against former board members and with proposing actions and presenting areas where action is needed to the senate.

- Based on the results of the audits of practices within the executive board, the senate resolved, in its special meeting on September 1, 2023, to immediately dismiss Prof. Alexander Kurz from his position as a member of the executive board of the Fraunhofer-Gesellschaft. The general assembly and Fraunhofer employees received an immediate notice from the senate regarding the change. In its meeting on October 26, the senate then established a senate committee for the election and re-election of executive vice presidents and tasked it with identifying a suitable candidate to lead the Research, Transfer and IP Management (VA) executive unit and presenting that person to the senate by the time of its June 2024 meeting. Prof. Holger Hanselka is acting in this role until the position is filled.

- The senate also agreed to the creation of the Fraunhofer Spain Research Foundation, a foundation organized and existing under Spanish law, by the Fraunhofer-Gesellschaft as the sole founder with the purpose of establishing this foundation as the legal entity supporting the planned Fraunhofer Center for Applied Theragnostics and future research units operated by Fraunhofer institutes in Spain.

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

The senate thanks the executive board and all employees of the Fraunhofer-Gesellschaft for all their hard work and dedication and their successful work in the financial year 2023. | am confident that with these levels of dedication and the tremendous expertise and excellence of all our employees, we will be able to craft a successful future.

Hildegard Müller
Chair of the senate of the Fraunhofer-Gesellschaft

"We need to combine a drive to innovate with government support to benefit our future."

Otto Fricke

Attorney at Law | Bundestag Member | Member of the Free Democratic Party (FDP) Federal Executive Board | Budget Policy Spokesperson of the FDP Bundestag Parliamentary Group

Otto Fricke completed his studies of law at the University of Freiburg in 1992 and passed the second state examination with honors in the state of North Rhine-Westphalia in 1995. A practicing attorney, Fricke served briefly as an advisor for the FDP parliamentary group in the North Rhine-Westphalia Landtag and then became a parliamentary advisor to the FDP Bundestag parliamentary group until 2002. Born in Krefeld, he has worked at law firm Fricke & Fricke since 1995. From 2014 to 2017, Fricke practiced law while also holding a position as a partner at international corporate consulting firm CNC — Communications & Network Consulting AG.

He has been a member of the Bundestag since 2002 and has served on the budget committee during five legislative periods to date, including chairing the committee during the 16th legislative period, which ran from 2005 to 2009 (the first cabinet under Angela Merkel as chancellor). Fricke recalls that a number of crises have been successfully navigated through budget policy in recent years, and he is an outspoken proponent of returning the German federal budget to its normal scale, in keeping with the constitution. With a brother who is a mechanical engineer, Fricke views technology as the key to solving many of the problems we face today: "We need to combine a drive to innovate with government support to benefit our future. We often underestimate the influence of private investment, but it accounts for about 80 percent of the total. Unleashing this private appetite for investment on the government side is the only way we will overcome the challenges to come."

In addition to his role on the budget committee, Fricke is a member of the FDP federal executive board. He also sits on the Bundestag legal affairs committee, finance committee, trust panel, and the special panel on the European Financial Stabilisation Mechanism (EFSM). Fricke, who is a father, also holds other positions, including chairing the German–Dutch parliamentary group and serving as a member of the board of trustees of World Vision Deutschland e. V. and of the Leo Baeck Foundation. He was awarded the Cross of Merit of the Federal Republic of Germany in 2020 in recognition of his achievements. He is also a Grand Officer of the Order of Orange-Nassau.

Photo: Otto Fricke / Christian Kaufels

New senate members

"To keep up with the rapid pace of change, more social innovation will be needed as well. Social innovation is the driver of transformation across society. It has the potential to make our economy and society sustainable and future-proof and the power to change the ways we address crises and our habits of coexistence, work, and consumption."

Prof. Anja Reinalter

Professor of Social Work with a Focus on Youth Work at Kempten University of Applied Sciences | Bundestag Member | Whip of the Alliance 90 / The Greens Bundestag Parliamentary Group

Anja Reinalter has been a member of the Bundestag since 2021. She serves as party whip, member of the parliamentary group board, and member of the board of directors responsible for human resources of the Alliance 90 / The Greens Bundestag parliamentary group. She has a full seat on the education, research and technology assessment committee and is a deputy member of the committee for scrutiny of elections, immunity and the rules of procedure.

Reinalter earned a doctorate in education from Goethe University Frankfurt and is a professor of social work with a focus on youth work at Kempten University of Applied Sciences. She believes training, continuing education, and lifelong learning are pivotal instruments in achieving the necessary transformation of the working world. To Reinalter, equality between vocational and academic education is a goal for both the academic field of education and education policy generally.

She entered politics as a result of her volunteer activities. Reinalter has been a member of the city council and district legislative body for the district of Biberach since 2009. She received the Helene Weber Prize for outstanding work in municipal policy in 2011. From 2019 to 2021, she served as the first chair of the nonpartisan Women's Council of Baden-Württemberg. "It's not just about talking about something together. It's about making something better together and putting it into action. I'm an advocate of diversity in committees. If as many walks of life as possible are represented in the democratic process, we can shape a politics of greater fairness for everyone."

Asked how the evolving needs and requirements across society should be addressed fairly and how to achieve sustainability and future-proof our economy and society, Reinalter calls for more social innovation and creatively minded research as a basis for policies rooted in science.

Photo: Andrea Ege

"When we skimp on education, all of society ends up paying a high price."

Sönke Rix

Early Childhood Educator | Bundestag Member | Deputy Chair of the Social Democratic Party (SPD) Bundestag Parliamentary Group

Sönke Rix, born in Eckernförde, has been a member of the Bundestag since 2005, representing the Rendsburg-Eckernförde electoral district. He was a member of the family affairs, senior citizens, women and youth committee from 2005 to 2021. Today, he is the deputy chair of the SPD Bundestag parliamentary group for the areas of family affairs, seniors, women and youth and of education and research. He is also a member of the board of the Parliamentary Left group within the SPD.

Rix's years of work on the family affairs, senior citizens, women and youth committee were informed by his experience as a state-accredited early childhood educator. During his education, he attended the Vocational School of Social Pedagogy in Kiel. During that time and afterward, he worked at Integrierte Gesamtschule Eckernförde (now Peter-Ustinov-Schule), a comprehensive school. Rix completed his mandatory civil service and probationary year at inclusion organization Eckernförder Werkstatt, part of charitable organization Norddeutsche Gesellschaft für Diakonie. He also worked there as a specialist in work and vocational development. In addition, Rix was involved in the body representing employees at Werkstätten Rendsburg-Eckernförde, another organization dedicated to fostering inclusion. He remains a member of the ver.di trade union.

Rix believes vocational training is the ticket to a self-determined life, including working life. He is a proponent of a basic income to support children with a focus on social justice, the Startchancen program, which is geared toward supporting schools with high percentages of disadvantaged students, a legal guarantee of a spot in vocational training or education, and the opening up of student financial aid to allow for broader participation. Rix argues that education, whatever the end goal — from master's degree to master craftsperson's certification — should be decoupled from a person's original family circumstances. "We need an education system that gives all young people the chance to live up to their full potential. That would help with the shortage of skilled workers, too," Rix notes. "After all, when we skimp on education, all of society ends up paying a high price."

Community engagement and protecting minorities are also top priorities for Rix. He has volunteered as a legal guardian with the Local Court of Eckernförde since 2000.

Photo: Linda Schmidt

Review of Fraunhofer research

- Fraunhofer world records
- Projects and results
- Awards
- People in research
- Selected transfer activities
- Initiatives

Fraunhofer world records

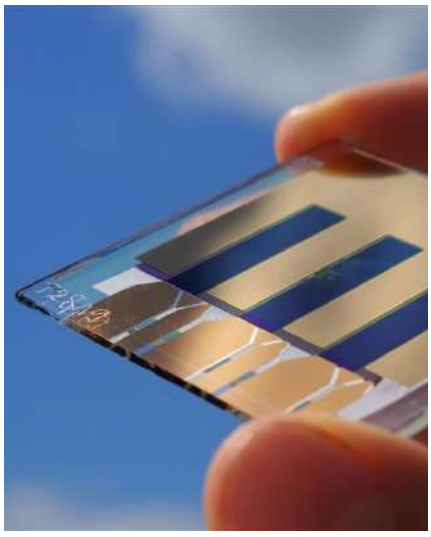
Setting standards for heat pump systems worldwide

Power electronics for innovative heat pumps

Fraunhofer researchers have been working on the ElKaWe flagship project since 2019 with the goal of developing high-efficiency electrocaloric heat pumps as an alternative to the currently widespread technology involving compressors and refrigerants. An ultra-efficient circuit topology for voltage converters based on gallium nitride (GaN) transistors with 99.74 percent electrical efficiency was finalized at the Fraunhofer Institute for Applied Solid State Physics IAF in July 2023. The GaN-based multilevel DC/DC converter is setting standards worldwide. Increased electrical efficiency leads directly to a higher coefficient of performance for the entire heat pump system, making it a milestone on the road to more-efficient heat pumps. Realizing a high coefficient of performance in electrocaloric heat pumps requires very high efficiency in materials, electronics, and heat transfer alike. Further research is still needed, but in the future, electrocaloric heat pumps could become a more efficient, fully emission-free solution for heating and cooling.

Organic solar cell with 15.8 percent efficiency

At the Fraunhofer Institute for Solar Energy Systems ISE and the Materials Research Center FMF of the University of Freiburg, the record last set by the team in September 2020 for a 1-square-meter organic solar cell was beaten in July 2023. The new solar cell established a new world record in this category again with an efficiency of 15.8 percent. The improvement of the record solar cell was primarily achieved by using an anti-reflective coating through which more light is absorbed into the photo-active layer of the cell, thus generating a higher current. The thin coating system required for the coating — deposited using a sputtering process — was also developed at Fraunhofer ISE. Organic solar cells could open up new fields of application for solar energy, as these cells are ecofriendly and inexpensive to produce as well as being flexible, plus they can be made transparent.



Anti-reflective coating for higher efficiency

Cryogenic drive inverter for electric drives in aviation

Drive inverter for electric flight

Compact, lightweight electric drives are essential to the electric aviation of the future. Superconductive systems, in which electrical current flows with almost no resistance and barely any losses, would be a good solution. This enables maximum performance in terms of efficiency, weight, and installation space. Many electrical conductors do not become superconductive until they reach cryogenic temperatures. And that means all of the drive components, including the complex inverter, must be designed for these kinds of conditions. The Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen has demonstrated a cryogenic-capable 500 kW drive inverter for the first time. It is cooled with liquid nitrogen at 77 Kelvin (K), corresponding to –196 degrees Celsius. The cryogenic inverter is the result of a cooperation with Airbus UpNext. As part of its ASCEND program, Airbus is now building a prototype of a fully cryogenic electric aircraft powertrain. The Fraunhofer IISB drive inverter has made this possible in the 500 kW power class for the first time.

Photos: Fraunhofer IAF, Fraunhofer ISE, Fraunhofer IISB

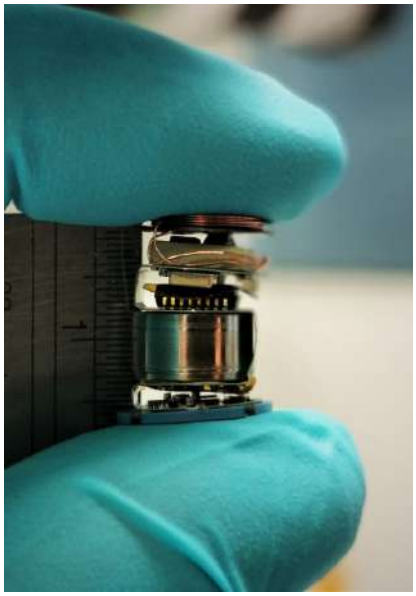
Unprecedented pixel density in OLED microdisplays

OLED microdisplays were previously limited in pixel quantity and size, with the maximum pixel density previously about 8,000 dpi (dots per inch). Higher pixel densities are not possible using traditional production methods, which involve conventional CMOS technologies on 200-millimeter wafers. The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP presented OLED microdisplays with an unprecedented pixel density of 10,000 dpi for the first time at SID Display Week in Los Angeles in May 2023. The first OLED microdisplay with 10,000 dpi has tiny, 2.5-micrometer pixels with a display diagonal of 0.18 inches. The CMOS backplane was designed and produced with small-node technology in a 28-nanometer CMOS backplane process on 300-millimeter wafers. The new backplane technologies also allow control concepts that can reduce the current consumption of mobile applications. The research, conducted as part of the Backplane interdisciplinary project, was funded by the Saxony State Ministry for Economic Affairs, Labor and Transport. The Microdisplays and Sensors business unit at Fraunhofer FEP was integrated into the Fraunhofer Institute for Photonic Microsystems IPMS with retroactive effect from January 1, 2024.

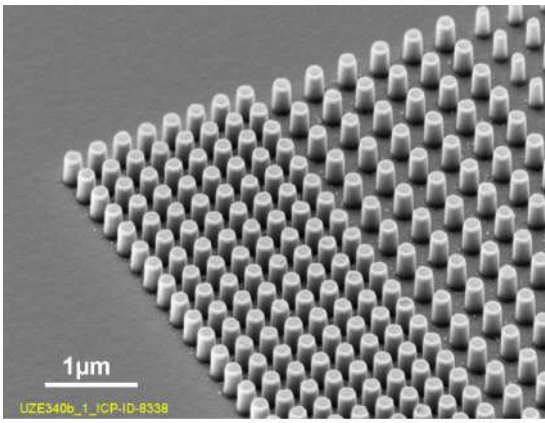
OLED microdisplay with the world's smallest pixels

The world's smallest impedance spectroscopy system

At 11 x 16 square millimeters, the Fraunhofer Institute for Reliability and Microintegration IZM developed the world's smallest system for impedance spectroscopy with its partners Micro Systems Technologies (MST) and Sensry GmbH. The sensor consists of a biocompatible, water-tight polymer. Six sensors were placed next to two electrodes to create a frequency spectrum from a medium. The developer group overcame the challenge of extreme miniaturization several times: for example, with the coil diameter for wireless charging (10 millimeters) or with the IoT system. This is located in a six-layer interposer; the electrodes for the impedance spectroscopy were placed in a 0.5-millimeter-thin ceramic plate from MST. Sensry GmbH devised the clever design structure. The flexible, biocompatible circuit board with over 70 components made of liquid crystal polymer was produced by MST in four layers. Electrochemical impedance spectroscopy fundamentally unlocks diagnostic options for a wide range of different applications, such as material studies and endoscopy.



Extremely miniaturized spectroscopy capsule for a wide range of diagnostic options



Electron microscope image of the meta-grid

30-centimeter metasurface

"Metasurfaces" could be an alternative to lenses and mirrors. Previously, the function of a lens or mirror was defined by macroscopic geometry, which is why they are thick and curved. Metasurfaces, by contrast, concentrate their entire optical function in a nanostructured surface. This means that in theory, metasurfaces can be produced to be much thinner than lenses. However, thus far it has only been possible to produce surfaces of a few square millimeters for applications in science and research — which is not yet enough for many industrial applications. In the spring of 2023, researchers at the Fraunhofer Institute for Applied Optics and Precision Engineering IOF succeeded in producing the world's first metasurface with a diameter of nearly 30 centimeters. To achieve this, they used a special writing strategy when illuminating the nanostructures with electron beam lithography. In this method, called character projection, complex patterns are divided into smaller units. An electron beam is then used to create each of these small patterns in turn on a surface in parallel with high precision and efficiency and at a comparatively high speed. The scientists published their method in the *Journal of Micro/Nanopatterning, Materials, and Metrology.*

Photos: Fraunhofer FEP, Fraunhofer IZM, Fraunhofer IOF

Projects and results

Five social goals for a future worth living

DIGITAL TRANSFORMATION 1

FULLY CIRCULAR ECONOMY 2

COMPLETE ENERGY TRANSITION 3

AFFORDABLE HEALTHCARE 4

SECURITY AND A RESILIENT SOCIETY 5

Digital Transformation

Real-world production machine (left) in the metaverse

Energy-efficient heterogeneous high-performance computing

The industrial metaverse at your fingertips

The metaverse is made up of interactive, immersive 3D environments. Extended reality (XR) technologies such as smart glasses, VR headsets and gesture input enable seamless interaction between the real and digital worlds. The industrial metaverse focuses on professional applications in industry and society, spanning fields such as transportation, plant engineering, urban development, and medicine. It can be viewed as the next stage of the digital transformation, following Industry 4.0. Key technological building blocks of any metaverse include digital twins, simulations, XR technologies, artificial intelligence (AI), blockchains, and data spaces. Because the industrial metaverse offers such a wealth of technological potential, the Fraunhofer ICT Group has dedicated an entire strategic roadmap to this topic within its research portfolio. The 20 institutes that make up the group act as technology suppliers and advisors on the planning and execution of use cases involving industrial metaverse technologies.

The 5G Troisdorf IndustrieStadtpark (Troisdorf 5G industrial park) project, which received funding from the German federal government, realized metaverse applications for remote maintenance and training in mechanical engineering and production applications. A technology demonstrator was presented at the Hannover Messe in 2023 and at the German federal government's 2023 open house event. The technological basis comprises 5G Internet, remote rendering of CAD data, and mobile mixed reality and virtual reality headsets. A digital twin was developed for the production machine operated by project partner ZWi Technologies, which is used on the production line at Kuraray Europe, another partner in the project. The machine's digital design data are custom-displayed in the user's field of vision by the headsets, which also present additional information. Communication among geographically dispersed users is supported by avatars, pointing gestures, direct manipulation, and audio and video communication. This enables distributed learning scenarios for the operation and maintenance of the machine, for example, including active dialogue in virtual space. The project coordinator is the Fraunhofer Institute for Applied Information Technology FIT.

Saving electricity with top digital performance

The digital transformation is opening up promising possibilities, but the underlying systems need to be made more energy-efficient. That is the goal of the NAAICE joint research project. The project is developing network-attached accelerators for energy-efficient heterogeneous high-performance computing (HPC).

This type of computing is used in fields such as climate modeling, astrophysics, and biology. It requires powerful processors, which in turn need a lot of energy. The NAAICE consortium is working to harness capacity in HPC data centers more efficiently. Conventional data centers generally use computers that are built on a base of homogeneous standard components and used for many different processes. For HPC applications, they typically utilize only specific parts of a standard computer, so a lot of capacity is lost. By contrast, the NAAICE partners are developing a heterogeneous system architecture in which computers are flexibly equipped for specific applications. To achieve this, the team is working with special integrated circuits known as field programmable gate arrays (FPGAs), which allow for new functions to be added continuously. The project's core technology is the novel concept of the network-attached accelerator (NAA), which is based on FPGAs. It was developed at the Fraunhofer Institute for Telecommunications, Heinrich-Hertz-Institut, HHI, Berlin. Unlike in previous concepts, in which FPGAs are integrated into data centers, NAAs are decoupled from the server processors. They are connected via the network instead, making them dynamically usable. Ultimately, they offer both more flexibility and lower energy consumption due to improved capacity utilization. The partners' current development targets include software for integrating NAAs into HPC data centers.

NAAICE was launched in 2022 with funding from the GREEN HPC line provided by the German Federal Ministry of Education and Research (BMBF). Along with Fraunhofer HHI, the University of Potsdam, the Zuse Institute Berlin, the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences, and PERFACCT GmbH are involved in the project. The results will be made available as open source software at the end of the project.

Photos: Fraunhofer FIT, shutterstock/aimediaPL

Digital Transformation

Flexible production architecture helps with supply chain disruptions

Infrastructure for development of innovative computers

Production architecture for the factory of the future

The manufacturing industry faces a number of challenges, including market volatility, supply crises, and rising energy prices. To address these factors, researchers have developed a modular and flexible production architecture in the Fraunhofer flagship project SWAP, which was launched in 2020. The project is disrupting the static structures and schematic processes of conventional production facilities and bringing fresh dynamism to the processing of work steps. It incorporates both the end product that is being manufactured and the machine technology required to manufacture it, including robots and autonomous transportation systems. To achieve this, the researchers are developing a standardized, semantically simplified language to describe machines, processes, and products. This language, the Production Flow Description Language (PFDL), is used to define the end product or component before manufacturing begins so that the desired special features can be added afterward. Once the orders are written up, they are processed autonomously by machines or robots.

This creates a smart and adaptable production environment. The new approach allows each order to be executed efficiently and adapted individually to the requirements. Conventional manufacturing, with its standardized workstations, cannot achieve the same case-by-case flexibility. Manufacturers can now adapt processes on the factory floor flexibly to suit their targets. The project consortium has already produced optics made out of polished metal — not glass — for a laser telescope based on the principle of the SWAP-IT production architecture developed in the project. The innovative production method offers options for lower-cost production than conventional methods for space telescopes in New Space and more.

SWAP should be viewed as a continuation of Industry 4.0 megatrends, featuring technologies such as sensors, connectivity, and digital twins. The researchers are also working on a practical process model for implementation purposes to make it easier for businesses to switch to the innovative production architecture.

Test lines for next-generation computers

Processing-intensive technologies such as artificial intelligence (AI) and edge computing are pushing traditional digital computers to their power limits. Quantum computing (QC) and neuromorphic computing (NC) open up fundamental opportunities for next-generation computing technologies. Without these, many competition- and security-critical missions would be impossible going forward.

The Research Fab Microelectronics Germany (FMD) is supporting the emerging next-generation computing ecosystem with its infrastructure and scientific know-how. The goal is to enable cutting-edge hardware development, particularly within the framework of the Quantum and Neuromorphic Computing Module — Module qnc funding line. The objective of the FMD-QNC project is to enable partners from the research, development, and innovation sectors and businesses to quickly implement their findings from lab settings in prototype and small series form. This is made possible by the extended process options that are part of the FMD-QNC project. In the fall of 2023, the QNC Space deep tech accelerator, which is part of FMD-QNC, opened up an easy way for research groups, founders, start-ups, and SMEs to access FMD-QNC partners' infrastructure for the first time.

The FMD-QNC funding project of the German Federal Ministry of Education and Research (BMBF) is supplemented at the European level by the PREVAIL funding project. Several research organizations — CEA-Leti (France), Fraunhofer (Germany), imec (Belgium), and VTT (Finland) — are working to create an interconnected 300-millimeter technology platform that will unlock possibilities for chip prototypes for AI or neuromorphic computing. Project activities within PREVAIL and FMD-QNC are interconnected. They represent important preparations for the technological foundation of the European Chips Act.

Photos: Fraunhofer IFF, Fraunhofer IPMS

Fully circular economy

Development of bioplastics made of polybutylene succinate

Finger orthoses made from fully compostable plastic

More types of PBS bioplastic

Recyclable and biodegradable plastics made from locally available plant residue instead of petroleum: That is the goal for the 18 partners working on the RUBIO project, which is funded by the German Federal Ministry of Education and Research (BMBF). The Fraunhofer Institutes for Applied Polymer Research IAP and for Microstructure of Materials and Systems IMWS are participating in the project. Fraunhofer IAP is developing new types of a bioplastic called polybutylene succinate (PBS) that will be more versatile than before. Fraunhofer IAP worked with POLIFILM EXTRUSION GmbH, in the state of Saxony-Anhalt, to develop a PBS film suitable for shipping pouches. The German company produces plastic films for the construction, agriculture, and automotive sectors as well as other industries. Cooperation between the applied research sector and businesses has made it possible to produce these films using standard extrusion systems, unlocking options for further development geared toward the needs of industry. The polymer experts at Fraunhofer IAP are providing support in terms of the methods used to synthesize new types of bioplastic, but that is not all. They are also transferring the results from the laboratory and pilot plant to the industrial pilot scale at the Fraunhofer Pilot Plant Center for Polymer Synthesis and Processing PAZ. At the Processing Pilot Plant for Biopolymers Schwarzheide, newly developed PBS types and mixtures are being studied with an eye to various criteria, such as thermoplastic processing, biodegradability, recyclability, and printability.

Few plastics processors have been bold enough to switch to bioplastics so far. Issues with supply chain reliability, higher costs, too little choice of different types of bioplastics, and questionable suitability for certain applications pose serious obstacles. Recycling, too, is only worthwhile for plastics that are present in large quantities in waste streams. With all this in mind, the RUBIO project consortium is continuing to develop PBS bioplastic. In the future, the goal is to source the raw materials for the plastic from local residue and waste — from biogas plants, agricultural operations, or paper production. If they are successful, shorter transportation distances could then even lower the prices.

The biological side of Industry 4.0

How can automotive manufacturing be made sustainable? A consortium led by the Fraunhofer Institute for Production Systems and Design Technology IPK has developed pilot processes for sustainable value creation as part of the BioFusion 4.0 funding project (German Federal Ministry of Education and Research, BMBF). Partners included Mercedes-Benz AG, Werner-von-Siemens Centre for Industry and Science e.V., and Technische Universität Berlin. The 13 entities involved developed solutions to support workers through biointelligent assistance systems and solutions for the use of biogenic materials, for example.

As one use case, an orthosis for component assembly in automotive production was developed: Intelligent algorithms are used to produce individual 3D bioplastic orthoses for workers' hands. The bioplastic is made from grease or fat, making it 100 percent compostable. The consortium also devised a multi-agent system that can be used to automatically control the distribution of production orders. Workers can use a dashboard to track how far along orders that have been received are in the process, visualize any workstations that are down, and get support with automatic adjustment of production steps. This kind of self-organized process control allows production companies to operate with greater flexibility and resilience.

A product's individual lifetime carbon footprint is also calculated. The aim is to incorporate these data into the Catena-X nonprofit organization via the Fraunhofer network. This collaborative, open data ecosystem represents the largest automotive industry project in relation to future production concepts: trusted data exchange among all stakeholders in the automotive industry — from the initial supply stage right through to the original equipment manufacturer (OEM). This exchange is based on the software services of International Data Spaces (IDS) and Gaia-X.

Photos: POLIFILM, Fraunhofer IPK / Larissa Klassen

Fully circular economy

The project team, visiting a claim site

Lithium carbonate like that produced in South America

Reducing "forever chemicals"

One of the most serious forms of environmental degradation caused by humans is the contamination of soil and water with per- and polyfluoroalkyl substances, or PFAS. They are found in everything from dental floss and outdoor apparel to fire extinguishers and crop protectants, along with many other products. PFAS, some of which are harmful to human and animal health, are also known as "forever chemicals," as they are extremely stable. Removing them is a laborious process. Activated charcoal filtering, for example, binds PFAS but does not eliminate them, meaning that the residue must be disposed of or stored as special waste.

Researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB have succeeded in developing a plasma method of energy-efficiently removing PFAS from contaminated water. The plasma is generated by applying high voltage between the electrodes of a combined glass and stainless steel cylinder. The contaminated water then flows along the outside of the (stainless steel) electrode. The energy-rich plasma atmosphere breaks apart the PFAS molecule chains, shortening them. The process is repeated several times in a closed loop. The molecule chains grow shorter each time they pass through until they have been broken down entirely. The AtWaPlas (Atmospheric Water Plasma Treatment) joint research project was carried out in cooperation with Aachen-based industry partner HYDR.O. The company, which specializes in cleaning up contaminated sites, supplied the water samples. The plasma method can also be used with the same setup to clean up other forms of water pollution, such as medication residue, other industrial chemicals, or plant protectants. As the next stage in development, these kinds of plasma systems could also be set up as a standalone purification stage at wastewater treatment plants or deployed as mobile units to contaminated open space.

AtWaPlas received funding from the German Federal Ministry of Education and Research (BMBF) as part of the Wasser: N initiative.

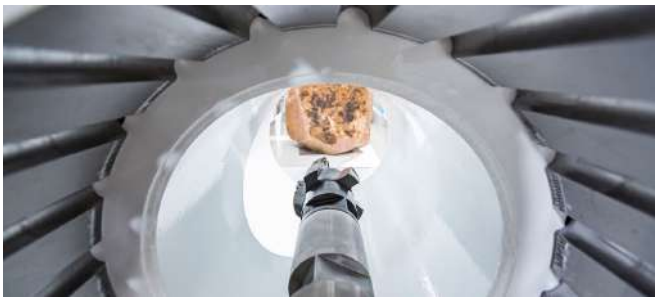
Domestic lithium from geothermal systems?

Lithium is the key raw material driving the energy transition, especially for the batteries needed for electric mobility. Germany remains dependent on imports — primarily from Australia and South America, produced under environmentally damaging conditions. But lithium is also found in Germany — on the Upper Rhine Plain, in the Ore Mountains, and in the North German Basin.

The trigger for the most recent research work was a study by Karlsruhe Institute of Technology (KIT) that was named an outstanding paper of 2022. The KIT researchers demonstrated that thermal water at a depth of several kilometers has a high concentration of lithium ions. Since then, several initiatives have been under way to study how the valuable metal can be combined with hydrothermal geothermal systems. Among those involved are EnBW AG, Vulcan Energie Ressourcen GmbH, the Fraunhofer Institutes for Chemical Technology ICT and for Physical Measurement Techniques IPM.

First, the lithium ions must accumulate through adsorption and then be released using desorption solutions. The lithium chloride produced in this way can be converted to lithium hydroxide through electrolysis and then traded in this form as lithium. A first lithium ion screen was produced under the auspices of KIT. It is based on a lithium manganese oxide with a special crystalline structure known as a spinel and was made using hydrothermal synthesis. The consortium is working to refine the screen and improve the method's cost-effectiveness. An optical sensor that enables spectral material analyses in ongoing processes helps with this. This development from Fraunhofer IPM is intended as a replacement for the costly, time-consuming, and laborious lab measurements that were previously needed for precisely controlling the time to change the through-flow direction in the lithium ion adsorption and desorption process. The sensor is to undergo testing during real-world operation at a geothermal site in the near future.

Complete Energy Transition



Drilling to explore geothermal energy

Modeling the expansion of the electrical grid

Drilling to harness geothermal energy

Water from decommissioned mines can contribute substantially to municipal heating and cooling needs. "Cold local heating networks" can be used to distribute heat to surrounding buildings. Heat pumps there are a very efficient option for heating the water to domestic hot water levels, as they supply heat pumps in surrounding buildings at even low working temperatures. Many of the decommissioned coal mines in Germany's Ruhr region contain large reservoirs of water. The D2Grids project, located on the grounds of a former Opel plant in Bochum, offers a blueprint for grid-connected low-temperature heating and cooling solutions in northwestern Europe. The former Dannenbaum coal mine is to be used to provide a climate-friendly supply of warm and cold water for the urban district being developed on the former Opel grounds (approximately 70 hectares). Pumping tests conducted in the spring of 2023 confirmed that the geothermal potential is sufficient. That marked the start of construction of an energy center. Going forward, warm water at temperatures of 27–28 degrees Celsius is to be pumped from a depth of 807 meters, then heated to approximately 48 degrees Celsius using heat pumps, and finally fed into the network. For cooling supply purposes, "cold" water at a temperature of about 17 degrees Celsius will be pumped from a depth of some 340 meters. This will be enough to cover about 75 percent of local needs.

The Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG was responsible for the underground activities, such as drilling through a substrate packed with old mine parts, and the logistics for the extensive pumping tests. It also advised local utility company Stadtwerke Bochum on the overall energy concept, including geothermal systems, heat networks, underground reservoirs, and large-scale heat pumps. Using the water from the mine as an energy source is expected to reduce carbon emissions by about 3,200 metric tons a year compared to a conventional supply involving natural gas and electric compression chillers.

D2Grids is supported by the programs Interreg for northwestern Europe and Wärmenetze 4.0 (Heating Networks 4.0).

Electrical grid development — down to the block

Transmission system operators 50Hertz, Amprion, TenneT, and TransnetBW presented the first draft of the electrical grid development plan for 2037/2045 to the German Federal Network Agency in the spring of 2023. For the first time, the plan describes an electrical grid with which climate neutrality can be achieved by 2045. To do this, the Fraunhofer Institute for Energy Economics and Energy System Technology IEE modeled the regionalization of renewable energy using specific maps for the expansion of wind and solar energy facilities.

The plan expects present-day electricity consumption levels to double to more than 1,000 terawatt-hours. Serving that level of demand will require installed output from renewables to approximately quintuple to as much as about 700 gigawatts in 2045. Incorporating this high level of output into the electrical grid while also ensuring safe and reliable operation requires accelerated action to expand the grid. The regionalization study by Fraunhofer IEE models right down to the postal code level how the construction of additional wind turbines and solar farms will be distributed around Germany in the future. With separate areas for onshore wind energy and for solar arrays in open areas and on rooftops, various data sources were used to localize existing and planned facilities and set their output in relation to the power specifications for each federal state designated in the grid development plan. Known potential and areas identified in potential analyses were weighted according to various parameters, such as availability, suitability, soil quality, and potential for conflict and then assumptions were made regarding development with new installations until the relevant output specifications were reached.

The results are summarized in map form for the existing status as of 2022 and then for the two scenarios underlying the grid development plan, which are set for 2037 and 2045. This means the study by Fraunhofer IEE gives transmission system operators a detailed basis for developing the network with an eye to the future and bringing renewable energy to wider areas of the country.

Complete Energy Transition

Using carbon-free gas from ammonia for combustion

Power on the hood, not under it

Ammonia offers hope for the energy transition

Green hydrogen is a promising climate-neutral energy source. The cost of transporting and storing it remains an open question. At the same time, ammonia, known as a base material for fertilizers, could enjoy a whole new career as a storage medium for hydrogen. It can be liquefied at a moderate temperature of –33 degrees Celsius, plus it can bind more hydrogen at lower volume than can be achieved when compressing hydrogen at 700 bar. Liquefied ammonia is easier to transport than hydrogen. With all this in mind, the Fraunhofer Institute for Microengineering and Microsystems IMM is developing systems based on ammonia that can supply the infrastructure, transportation, and industrial sectors with clean energy on a mobile basis.

But there are still very few technologies aimed at using ammonia to generate energy. The researchers have found a solution to that issue, too: the AMMONPAKTOR reactor, which splits ammonia into nitrogen and hydrogen. This produces a cracked gas that can be burned as a source of fuel. A method of producing bricks with zero carbon emissions has already been demonstrated with an industry partner, using ammonia from green hydrogen. This energy source can also be used for mobile fuel cell applications such as vehicles or maritime vessels. A cracking reactor developed at Fraunhofer IMM features a subsequent purification stage, splitting pure hydrogen from ammonia that can be fed directly into PEM fuel cells in vehicles.

The AMMONPAKTOR reactor achieves efficiency of 90 percent in the process of converting ammonia back to hydrogen, compared to 70 percent for conventional technologies. The size has also been reduced by 90 percent compared to conventional reactors. The second-generation cracking reactor, which is currently in the manufacturing process and has a throughput of 25 kg/hour of ammonia, produces 70 kilos of purified hydrogen per day. The reactor is included in Fraunhofer's AMMONVEKTOR flagship project, which aims to develop an overall strategy for ammonia from production to transportation and use.

Solar cells on the hood and roof

The hood of a car, covered with a matching-color film made of integrated solar cells: This exhibit from the Fraunhofer Institute for Solar Energy Systems ISE drew throngs of visitors at IAA Mobility 2023. "Power on the hood," publisher VDI Verlag wrote on their portal ingenieur.de, and "Researchers produce solar power with an engine hood," ran the headline in the online edition of *Auto Bild*.

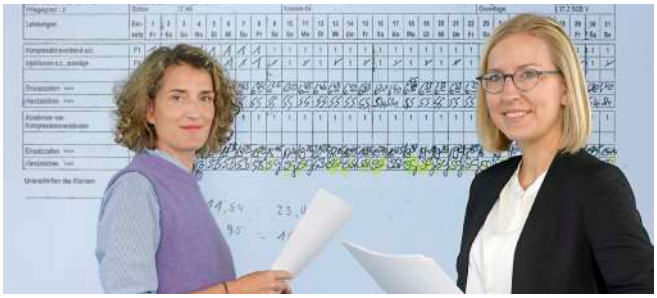
The challenges involved in building the solar cells into the hood of the vehicle were the area, the curved shape, and the substrate, which was made of sheet metal rather than the traditional solar panel backing of film or glass. The research teams from Fraunhofer ISE tested various solar cell types with different material combinations to use as much of the space available on the hood as possible and check their solutions' adhesive properties. After that, prototypes featuring different cell and wiring technologies underwent extensive lab testing to ensure their electrical output and the reliability and service life of the solar cell hood demonstrators. Laminating the surface with film creates a textured surface structure, which can be adjusted to match the vehicle's color using the MorphoColor® technology developed at Fraunhofer ISE. The hood exhibited at IAA MOBILITY has a rated output of 115 watts. It features 120 PERC shingle-style solar cells. The color is MorphoColor® Gray.

The technology can also be applied to metal car roofs, and it would also be lighter than solar panel car roofs made of glass. Taking the roof and hood together, the solar range of an electric vehicle in a city that gets a lot of sunshine, like Freiburg, could be as high as 4,000 kilometers a year. Back in 2017, a study performed by Fraunhofer ISE in collaboration with shipping companies found that a truck roof in Europe would have 5,000 to 7,000 kilowatt-hours of annual power generation potential. The technology behind the solar cells integrated on a film backing is suitable for both electric vehicles and those with internal combustion engines.

Illustration: Fraunhofer ITWM, photos: Fraunhofer IMM, Fraunhofer ISE

Affordable healthcare

Doctor's letters drafted with natural language processing (NLP)



Using AI to combat billing fraud in healthcare

AI to help with doctor's letters

Around 150 million doctor's letters are written every year in Germany, a time-consuming process. And yet, a large portion of the medical information involved is already present in text form. In the future, the laborious process of analyzing and further processing this information will be handled by natural language processing (NLP), a combination of algorithms and artificial intelligence (AI). To accomplish this, the method involves extracting information from texts and providing it in structured form. Processes like quality assurance, preparation of statistics, support for clinical decisions, and billing can all be streamlined in this way. RightCoding (RICO), a software program developed by the Fraunhofer Institute for Intelligent Analysis and Information Systems IAIS, is already in use. It greatly simplifies the coding and billing process at many hospitals. Doctor's letters will soon be generated automatically as well. A team from Fraunhofer IAIS plans to test a prototype for discharge papers at Universitätsmedizin Essen as early as 2024. The project is part of the SmartHospital.NRW flagship project, which itself is part of the KI.NRW expertise platform. Text, speech, and signal processing technologies are being studied in particular.

Scientists at Fraunhofer IAIS wrote a white paper titled "Natural Language Processing in der Medizin" (Natural Language Processing in the Medical Sector) that summarizes the overall possibilities that NLP opens up for the field of medicine. The paper highlights recent developments and current uses for AI in document-based processes in the medical field. Health data is currently one of the fastest growing data sets. At the same time, the healthcare sector faces numerous challenges, such as staff shortages, cost pressure, and information overload. The goal now is to work with healthcare institutions to tap into the full potential of AI-based automation, with particular attention to patient wellbeing and easing the workloads of healthcare professionals.

AI uncovers fraudulent healthcare billing

Billing fraud in the healthcare sector adds up to several billion euros in losses every year. The digital transformation of processes gives rise to new possibilities for systematically identifying fraud — whether in nursing care, hospital settings, or public administration. In the PflegeForensik project, researchers from the Fraunhofer Institute for Industrial Mathematics ITWM in Kaiserslautern joined forces with the office of the public prosecutor general in Dresden and the white-collar crime unit of the Leipzig police department to tackle billing fraud in the healthcare sector. The partners created a software solution that uses artificial intelligence (AI) to help with investigations. First, image processing was used to develop algorithms to automatically scan the mountains of paper and analyze them intelligently. The algorithms can do things like find signatures and associate them with the correct individuals. Comparing the rounds and schedules for nursing staff against billing data can flag potential instances of fraud.

To find these and other anomalies and analyze them digitally, the researchers worked with users to translate typical investigations into mathematical models. Training the AI algorithms involved first anonymizing several hundred documents and then manually marking them with particular properties. Working from this data as a basis, AI algorithms can then learn problem-related patterns. The solution was specifically developed to allow it to be adjusted to new data and improved or corrected over time. A workshop held to mark the project's conclusion, in 2023, gave representatives of law enforcement agencies, the judiciary, and health insurance funds an opportunity to try out a software demonstrator. The work received support from Germany's Federal Ministry of Education and Research (BMBF) under the Research for Civil Security program. The partners plan to continue the project and ideally create live software that offers maximum intuitiveness and ease of use while at the same time supplying results that can be used in court proceedings.

Photos: iStock.com/sarinyapinngam, Fraunhofer ITWM

Affordable healthcare

A digital ecosystem links many components together

Patient models help the healthcare system

Healthcare in rural areas

Medical care in rural areas needs an overhaul. A study by the Robert Bosch Stiftung found that some 11,000 general practitioner positions in Germany will be vacant by 2035, and nearly 40 percent of districts are at risk of a shortage of GPs. To counteract this trend, the Fraunhofer Center for Digital Diagnostics ZDD is working with several Fraunhofer institutes in the Neighborhood Diagnostics project with the goal of developing a digital ecosystem to help with diagnosis close to where patients live and to support medical treatment in rural areas. The idea is that this will relieve some of the pressure on doctors and specialized personnel and provide rapid, early diagnoses and high-quality care to patients, without them having to travel long distances.

All medical data are to be brought together in a single digital platform. Components will include home monitoring devices that measure markers of patient health such as blood pressure or blood sugar levels, along with wearables — small computer systems such as smartwatches worn directly on the body. These devices will use a Neighborhood Diagnostics app to transfer their measurement data to the platform. A warning is to be issued if any measurements seem unusual. Going forward, applications like these will allow the ecosystem to interpret data, arrive at diagnoses, and make recommendations for medications, physical therapy, and other medical services.

Fully automated health stations are a key part of the digital ecosystem, handling further tasks that would normally fall to medical practices and labs. Registered patients will receive various test kits so they can perform a nasal or throat swab or take a sample of capillary blood, for example. They will then return the kit with the specimen. The tests in the diagnostic devices will be performed autonomously within the station by sophisticated robots and, if necessary, held in cold storage. Depending on their individual health situation and diagnosis, patients could receive the results on-site, via the app or from their doctor. The model region of Brandenburg is the starting point for the trial phase, focusing on providing care for those with chronic conditions. The system is then set to be gradually expanded to rural areas all across Germany.

Ensuring that treatments have optimum effects

Point-and-click prevention, diagnostics and treatment: A system to support decision making, developed as part of the Fraunhofer MED²ICIN flagship project, is opening up new possibilities for the healthcare sector.

So far, patient data has often been kept in various different systems at different times and in different places. In MED²ICIN, the consortium for the Fraunhofer flagship project of the same name has developed a system that combines the data and helps medical professionals make decisions. In cooperation with Frankfurt University Hospital, the Fraunhofer institutes involved also incorporated the experiences of practicing physicians. An online survey of some 50 gastroenterologists from hospitals and medical centers confirms that the patient model meets the target objectives. A system like this can be expected to save 23 percent on costs and 35 percent on treatment times. Effective ways to curb healthcare spending are urgently needed in light of demographic trends and the huge shortage of skilled workers. In this digital patient model, users can access AI-based analyses and specialized medical publications and check the guidelines for treatment as well as the costs of each treatment option. A cohort module sets individual patient information in relation to data on similar diseases and conditions. This helps treating physicians identify the treatments with the best outcomes in specific cases. All of the information is presented in an easily understandable dashboard. Right now, the researchers are advancing the project at the European level with Finnish partners. Using 10,000 sets of patient data, they will continue to develop the model so that it can be incorporated into commercial systems and used in day-to-day medical care.

Illustration: Fraunhofer IESE, photo: Fraunhofer IGD

Security and a resilient society

Key cash supply points identified for emergency situations

Infrared imager in the ERNST small satellite

Supply of cash in a crisis

The global polycrisis of recent years has made it clear that people should be prepared for sudden emergencies such as widespread power outages or the failure of the IT and communication network — including the case of electronic payment systems, which typically stop working when these kinds of situations arise. In early 2023, an alliance of researchers and key stakeholders in the cash cycle published a security concept containing recommendations for how the cash cycle can be made more resilient. A project titled Resilience of Cash Supply — Security Concepts for Emergencies and Crises (BASIC) was coordinated by the Brandenburg Institute for Society and Security (BIGS). Researchers with the Supply Chain Services working group of the Fraunhofer Institute for Integrated Circuits IIS have developed an optimization algorithm to identify key cash supply points in Germany.

Working on specific scenarios, they used mathematical optimization to pinpoint the optimum supply of cash to supply points that should be able to maintain operations in a crisis. These specific ATMs or bank branches should be equipped with emergency power generators to keep them operational in a crisis, for example. Another area of focus for the project was harmonizing the specific emergency and crisis plans for all stakeholders in the cash cycle and further safeguarding working processes, especially those of cash and valuables service providers.

The project partners were Brandenburgische Institut für Gesellschaft und Sicherheit gGmbH (BIGS), Bundesvereinigung Deutscher Geld- und Wertdienste e.V. (BDGW), Cash Logistik Security AG, and the Supply Chain Services working group of Fraunhofer IIS. The consortium project received a three-year grant from the German federal government's Research for Civil Security program along with support from the German Federal Ministry of Education and Research (BMBF).

Small satellite detects hypersonic flying objects

The first small satellite mission for the German armed forces is due to launch into low Earth orbit in June 2024. Its mission is to detect the launch of ballistic missiles or hypersonic flying objects into low Earth orbit early on.

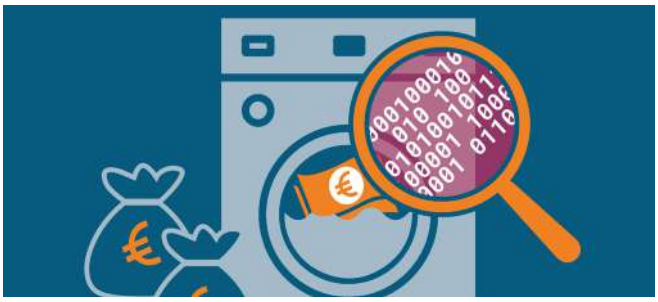
To achieve this, several Fraunhofer institutes led by the Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut, EMI developed a nanosatellite called ERNST. A cryogenically cooled infrared camera is the centerpiece of the satellite, which is about the size of a crate of beer. For effective early warning to enable interception measures, the surface of the planet is monitored in different short- to medium-wavelength infrared ranges. The detection concept, which was developed by the Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB, combines various spectral ranges to detect and track a rocket's infrared signature, which changes during the different phases of flight.

For ERNST and its mission, Fraunhofer EMI combined and modified available products from New Space and the defense segment with elements developed in-house. One special feature is the bionic-seeming optical table where the camera components are placed, which was made using generative manufacturing. Among other things, a radiator with a three-dimensional structure was incorporated. It discharges heat over a much smaller surface area than conventional flat radiators. To carry out its mission, the small satellite is equipped with a visual camera for georeferencing and a radiation monitor developed by the Fraunhofer Institute for Technological Trend Analysis INT. The monitor uses detector elements with various types of shielding to measure the total dose of radiant energy hitting the satellite, along with the influence of protons and neutrons.

If all goes well with ERNST's 2024 launch, the small satellite will then carry out its three-year mission and return to Earth afterward by unfurling a braking sail. The goal here is to demonstrate sustainable use of the space environment.

Security and a resilient society

Help with exploiting drone images



Zeroing in on suspected money laundering

Automated image exploitation for drones

Uncrewed aerial vehicles such as drones play an increasingly important role in the security sector, on search and rescue missions, and in defense. The Fraunhofer Institute for Optronics, System Technologies and Image Exploitation IOSB has been devising a modular video analysis system known as ABUL since 2005 for the LUNA drone, which the German armed forces have been using successfully for years. The system has undergone continuous further development during that time, in line with evolving requirements and research findings.

The video data collected by the drones is transmitted to ground stations via various data connections and then exploited by the personnel on duty there. ABUL was developed to support staff with tasks such as monitoring and exploitation to be carried out over several hours. The system features optimized real-time functions such as image stabilization for online reconnaissance. Over time, functions based on artificial intelligence (AI) have been incorporated for purposes such as detection, classification, and tracking of vehicles, people, and additional classes of objects. Offline reconnaissance mission features have been added, and image mosaics enable improved transmission of results. The basic idea behind ABUL is a dual screen system with an adjustable graphical user interface (GUI) for various sensor systems. The first screen shows a window containing the video streams from all sensors. It also provides control elements for efficient navigation and image processing by personnel. The second screen shows a map window with exploitation functions. In addition to multi-stream exploitation, cooperative exploitation of multiple workstations is also possible.

The ABUL system is used not only in the German armed forces' LUNA drone, but also by the Swiss air force, which has incorporated it into their new ADS 15 reconnaissance drone. The system is currently being optimized for a new field of application, protecting infrastructures with mast-based camera systems.

Enlisting AI to better identify money laundering

In the fight against money laundering, various analytical methods are used to verify financial transactions. The process typically flags a large number of potentially suspicious cases, each of which has to be reviewed individually by a specially trained analyst and reported to the relevant authority, the Financial Intelligence Unit (FIU). The FIU received about 300,000 reports a year in 2021 and 2022. A project called MaLeFiz aims to change that by harnessing AI and machine learning methods to make detecting money laundering more efficient. Having fewer false alarms will ease the burden on analysts at financial institutions in particular. The FIU and law enforcement agencies will benefit indirectly, as there will be fewer reports to process.

However, if the results delivered by these kinds of AI-based tools are to be usable in court, there are certain requirements that must be met. In particular, the decisions made by AI must be understandable (no "black box" decisions), and the reasons a transaction has been flagged as suspicious must be disclosed transparently. In keeping with this situation, the project team is exploring legal and ethical issues. For example, they are drafting a set of minimum requirements for AI-based tools used in sensitive areas that could touch on people's fundamental rights. Among other goals, these requirements are intended to ensure that it is possible to verify during an audit that AI-based tools are being used in compliance with applicable laws and that they are trustworthy. To align the AI as closely as possible to real-world application and take user needs into account wherever possible, the project partners are conducting interviews, workshops, and tests with users. The results are being incorporated into a demonstrator that is to be tested at banks first and foremost. The project is scheduled to conclude in the fall of 2025. The minimum requirements and additional project results will be published at that point. The project partners involved are Deloitte GmbH, the Fraunhofer Institute for Secure Information Technology SIT, Martin Luther University Halle-Wittenberg, Leipzig University, and the Center for Technology and Society at TU Berlin. The MaLeFiz project is funded by the German Federal Ministry of Education and Research (BMBF).

Photo: Fraunhofer IOSB, illustration: Fraunhofer SIT

Awards

Fraunhofer research prizes

Fraunhofer Prize for Human- and Environment-Centered Technology
This prize is presented by the Fraunhofer-Gesellschaft, the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation), and the former executive board members, institute directors, and associated supporters of the Fraunhofer-Gesellschaft. It is awarded every two years for achievements in research and development that improve people's quality of life or help make our world more sustainable. In 2023, the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) contributed for the first time to the prize money, which amounts to €50,000. The Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) supports research projects of the Fraunhofer-Gesellschaft that facilitate and accelerate the transformation to a sustainable economy and way of life. Its activities are guided by the United Nations' Sustainable Development Goals (SDGs).

Joseph von Fraunhofer Prize
Since 1978, the Fraunhofer-Gesellschaft has awarded the Joseph von Fraunhofer Prize to its employees for outstanding scientific achievements that solve practical problems. Criteria for awarding the prize include how new and innovative the scientific-methodical approach is, the advancement of knowledge, and the implementation of the scientific results in applications. Three Joseph von Fraunhofer Prizes were awarded in 2023, each one with €50,000 in prize money.

Hugo Geiger Prize
The Bavarian Ministry of Economic Affairs, Regional Development and Energy awards the Hugo Geiger Prize for outstanding doctoral theses 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.

Fraunhofer Prize for Human- and Environment-Centered Technology 2023

Satellite technology: Sustainable use of water in agriculture

A new satellite technology has made it possible to irrigate plants on a targeted, as-needed basis. It detects radiant heat from orbit and measures land surface temperatures. This allows researchers to deduce how much water a plant needs. Researchers from the Fraunhofer Institutes for High-Speed Dynamics, Ernst-Mach-Institut, EMI and for Applied Optics and Precision Engineering IOF, together with the companies constellr GmbH and SPACEOPTIX GmbH (both spin-offs of these institutes), have taken inspiration from the founding principle of constellr GmbH to develop the infrared camera LisR — short for Longwave infrared sensing demonstratoR. LisR was successfully tested on the International Space Station (ISS) in 2022. Based on these discoveries, constellr now plans to launch its own satellites into orbit. Leveraging the satellite network would make it possible to save 180 billion metric tons of water and 94 million metric tons of CO_2 annually starting from 2026 and increase global harvests by up to four percent.

Cassi Welling, Dr. Henrik von Lukowicz, Dr. Matthias Beier and Clemens Horch (from left)

Joseph von Fraunhofer Prize 2023

Microspeakers: Energy efficiency for earbuds

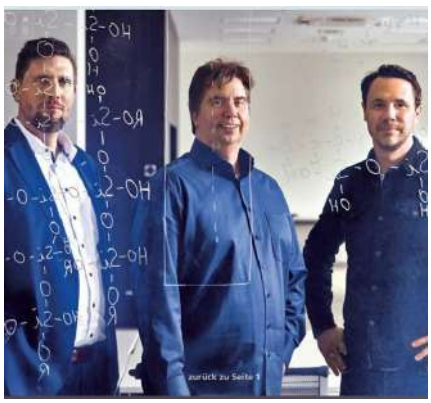
In the future, smart earbuds with direct Internet interfaces could substitute for many smartphone features. The foundation for this was laid by a team of researchers from the Fraunhofer Institute for Photonic Microsystems IPMS. The speakers developed there are made entirely of silicon, cost little to manufacture using microelectronic technology, and achieve the specified volume of 120 decibels without the high power consumption of an amplifier circuit. This is made possible by a completely new speaker design, among other things. Now, for the first time, the sound-displacing elements are positioned vertically inside a silicon chip. In order to commercialize the speakers, Arioso Systems GmbH was set up in 2019 as a spin-off from Fraunhofer IPMS and the research conducted at Brandenburg University of Technology Cottbus-Senftenberg. The spin-off was acquired by Bosch Sensortec GmbH in the summer of 2022 with the aim of developing cutting-edge products for the global mass market.

Dr. Sergiu Langa, Dr. Bert Kaiser and Dr. Holger Conrad (from left)

Joseph von Fraunhofer Prize 2023, EARTO Innovation Award

Building insulation: Sustainable, affordable building insulation with aerogels

Building insulation can make a substantial contribution to cutting carbon emissions. However, conventional insulation materials such as expanded polystyrene are based on petrochemical sources. Nils Mölders and Andreas Sengespeick from the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT and Christoph Dworatzyk from PROCERAM GmbH & Co. KG have succeeded in producing a sustainable, low-cost aerogel-based mineral insulation material that is suitable for mass production. Within just six years, the team developed a new aerogel manufacturing process that does not require any chemicals hazardous to the environment — from laboratory to pre-industrial scale. Manufacturing costs for the aerogels fell by 70 percent, and manufacturing time from more than 10 hours to just 4 hours. The project also received the Innovation Award from the European Association of Research and Technology Organisations (EARTO) in the "Impact Expected" category in October 2023.



Christoph Dworatzyk, Andreas Sengespeick and Nils Mölders (from left)

Joseph von Fraunhofer Prize 2023

Audio technology: Customized listening experiences in 3D

A team from the Fraunhofer Institute for Integrated Circuits IIS is developing a complete system that covers the entire chain from sound production to transmission through to playback. MPEG-H Audio includes production tools, file and transmission formats, and innovative playback methods as well as software solutions for integrators. One example of the many developments around MPEG-H Audio is the immersive object-based music format 360 Reality Audio from the electronics company Sony. It can already be found on many streaming services. An album produced with this technology even won the Grammy for Best Immersive Audio Album in 2023. The MPEG-H Audio system brings the three-dimensional world of sound to more and more playback devices. This Fraunhofer IIS technology uses a process that clearly sets it apart from other 3D sound systems: Instead of simply using conventional soundtracks, the production process works with audio objects.

Adrian Murtaza, Harald Fuchs and Dr. Achim Kuntz (from left)

Photos: Fraunhofer / Piotr Banczerowski

Hugo Geiger Prize 2023
First place

New material for semiconductor memory

In his dissertation with the Fraunhofer Institute for Photonic Microsystems IPMS, Dr. Maximilian Lederer developed methods of producing hafnium oxide. This makes it possible to realize faster, energy-saving and secure RAM or USB storage and neural networks for artificial intelligence. The ferroelectric capabilities of hafnium oxide, a material used in semiconductor technology, were not fully understood previously, so it could not be used reliably in non-volatile ferroelectric memory (FeRAM). Lederer used new methods to study the material's crystalline microstructure and find out how physical processes taking place at the molecular level and deposition and process conditions affect the ferroelectric switching behavior of HfO_2. Using this as a basis, he developed new production processes that optimize the material's growth or composition, such as the electric field-induced crystallization that he showed for the first time. Globalfoundries, a chip manufacturer based in Dresden, is currently testing ferroelectric storage components in a research and development line.

Dr. Maximilian Lederer

Hugo Geiger Prize 2023
Second place

Efficient 3D audio with superior sound quality

Through his dissertation with the Fraunhofer Institute for Integrated Circuits IIS, Dr. Sascha Dick has contributed to the high-quality, efficient transmission and processing of 3D audio signals. He conducted extensive listening tests and discovered that the accuracy of localizing spatially distributed sound sources can also be determined through data analysis. The psycho-acoustic model he developed on this basis describes how the spatial distribution of the volume emitted by different sound sources is perceived. This can be used as a foundation for aggregating the sources that are indistinguishable and reducing their number by a factor of ten — all while maintaining excellent sound quality. This makes it possible to develop efficient 3D coding algorithms that enable not only high-quality cinematic conversion for home theater use, but, thanks to significantly reduced data rates, real-time applications in virtual reality and gaming as well. Intelligent aggregation of sound sources can also help improve the intelligibility of speech, and thus improve acoustic accessibility.

Dr. Sascha Dick

Hugo Geiger Prize 2023
Third place

A novel approach to early detection of cancer

In her doctorate with the Fraunhofer Institute for Cell Therapy and Immunology IZI, Dr. Susann Allelein laid the groundwork for simpler liquid biopsies for faster cancer diagnosis by means of extracellular vesicles. Thanks to these particles, long viewed as mere cellular waste, liquid biopsies involving blood or urine samples could take the place of tissue biopsies in the future, eliminating the disadvantages of that method. Cells exchange information on their properties and components with each other via the extracellular vesicles in bodily fluids. In her groundbreaking dissertation, Allelein studied how these particles can be used for early detection of prostate cancer. She developed new methods to efficiently characterize the vesicles, which are about the size of viruses, and isolate the relevant ones among them from the many cellular information packets moving around the body. Although the protein specific to prostate cancer that she originally studied turned out to be unsuitable as a marker, Allelein laid important foundations for further research involving extracellular vesicles, whose potential extends beyond cancer diagnosis to precision treatment monitoring and development of vaccines.

Dr. Susann Allelein

Photos: Fraunhofer IPMS / Sebastian Lassak, Fraunhofer IIS / Paul Pulkert, Fraunhofer IZI / Michaela Grunert

Research competitions — national and international

German Logistics Award

Together with Dachser, the Fraunhofer Institute for Material Flow and Logistics IML received the German Logistics Award from German logistics nonprofit Bundesvereinigung Logistik (BVL) for the development of the Advanced Indoor Localization and Operations (@ILO) digital twin. Special AI-based algorithms built into the @ILO software interpret the data, collected in cycles lasting just seconds by hundreds of optical scanning units on the ceiling of the fulfillment center. The objective is to identify and localize each and every package directly and automatically. In the future, measurement capabilities will be added as well. A digital twin forms a full image of the warehouse and its processes that is always up to date. Employees receive this information, which is presented intuitively on mobile devices and displays.

Individual process flows between when goods are received and when they go out are accelerated by 15 to 35 percent. This eliminates the need to scan barcodes manually or take daily manual inventory of packages. Vehicles with local routes can start delivering faster in the morning, for example, so drivers gain valuable time amid rush-hour traffic. The technology was developed jointly at the Dachser Enterprise Lab and has already been implemented at two branch locations: Unterschleissheim, near Munich, and Öhringen, which is close to Heilbronn. The new technology is scheduled to roll out in stages, with the first stage starting in 2024 and additional European branch locations following after that.

The 2023 winners celebrate on behalf of the Dachser and Fraunhofer R&D teams

Technology Award

The secureAR project won the Technology Award at the conference marking the conclusion of the "Zukunft der Wertschöpfung" (Future of Value Creation) program funded by the German Federal Ministry of Education and Research (BMBF). The Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP is involved in the development. The consortium created a cross-industry cloud-based service platform with open industrial interfaces. These include an assistance system with smart glasses whose OLED microdisplay was developed at Fraunhofer FEP. The results are based on the latest research findings combining computer vision, machine learning, and data security. The service platform collects information along the entire value chain, from planning and production processes to system and plant maintenance, and enables location- and situation-based provision and visualization of data via the innovative AR assistance system. Industrial production sites operated by Airbus and Siemens were used as sample scenarios. The AR system was integrated into personal protective equipment for this purpose.

AR assistance system equipped with electricity-conserving 720p OLED microdisplays

Photos: Bundesvereinigung Logistik (BVL) e.V., Fraunhofer FEP

Prof. Karl Mandel (Fraunhofer ISC) and Dr. Oliver Höhn (Fraunhofer ISE) (from left)

European Research Council Consolidator Grant

The European Research Council (ERC) awards five-year Consolidator Grants valued at up to €2 million to promising postdoctoral researchers. Two Fraunhofer scientists will be able to intensify work on their projects starting in 2024. Prof. Karl Mandel from the Friedrich-Alexander-Universität Erlangen-Nürnberg and the Fraunhofer Institute for Silicate Research ISC is pursuing a project called SmartRust with the goal of transforming objects into material that can sense and communicate environmental influences. Mandel's aims include ensuring product safety and material reliability, enabling predictive maintenance, and making the complex recycling status of materials transparent. Dr. Oliver Höhn from the University of Freiburg and the Fraunhofer Institute for Solar Energy Systems ISE plans to advance his research on resource-friendly, ultra-thin, and high-efficiency solar cells as part of the PHASE project. Among other things, the funding will be used for a plasma etching system for semiconductor materials in main chemical groups III and V of the periodic table. PHASE aims to extend the concept of ultra-thin single solar cells to tandem solar cells, thus significantly reducing the cost and amount of materials used for the resource-intensive semiconductor part. Across Europe, 2,130 researchers had applied for the current ERC grant round. Just over 300 Consolidator Grants were awarded.

Prof. Kathrin Adlkofer is the founder of Cellbox.

Cellbox wins EIC Accelerator Award

Cellbox was spun off from what is today the Fraunhofer Research Institution for Individualized and Cell-Based Medical Engineering IMTE in 2016 with the idea of shipping live biological material for the first time. The solution developed there for transporting live cells or organoid systems at external temperatures and not frozen, as before, is increasingly important these days for applications such as treating severely ill patients with cell therapies (CAR-T therapies or with ATMPs) or for alternatives to toxicological animal testing in drug development. Previously, the cells or tissue had to be frozen with liquid nitrogen before being transported, for example from a hospital to a lab or between biotechnology and drug companies. This can harm sensitive cells. Cellbox is the first ever transportation system available to preserve these materials without freezing them. The Cellbox team currently has 15 members. They sell the company's transportable cell incubator worldwide, serving customers from Germany, elsewhere in Europe, the United States, and Asia, with a particular focus on China. In 2023, the European Innovation Council granted the Fraunhofer spin-off its Accelerator Award, one of the lines of funding under the EU's Horizon Europe program. The award comes with €2.5 million in base funding with the option of matching an additional €10 million in equity capital over the next few years. The spin-off plans to work with a number of other Fraunhofer institutes to further develop the Cellbox shipper for other applications, including the advanced therapy medicinal product (ATMP) market.

Photos: Cellbox Solutions / Lars Wehrmann, Fraunhofer ISC / Katrin Selsam, University of Freiburg

EIT Digital Challenge 2023

One example of transferring digitalization technologies to a broader market is Threedy, a spin-off of the Fraunhofer Institute for Computer Graphics Research IGD. Threedy had already won the Fraunhofer Founder Award in 2022. Then, in 2023, it was selected as one of Europe's ten most exciting scale-up start-ups in the Digital Challenge 2023 competition organized by the European Institute of Innovation and Technology (EIT). These are start-ups with especially fast growth. Threedy's instant3Dhub product is a platform for visual computing in industrial processes. The group of researchers got the idea for their spin-off in 2015, when a German automotive group placed an order with them. Threedy's client base is concentrated in the automotive and mechanical engineering sectors. With instant3Dhub, it provides 3D data to all of the areas involved at every step of the process, without complications and in real time. This simplifies processes, saves significant time, and takes quality and error management to the next level.

In addition to the central support offered for employees interested in starting their own business, Fraunhofer IGD also provides additional funding for spin-offs. Its objective is to intensify transfers from research to practice and from applications back to the research sector.

Christian Stein, Dr. Johannes Behr, Maik Thöner and Sascha Räsch founded Threedy (from right)

Otto von Guericke Prize

Franz Balluff and Thomas Hess from the Fraunhofer Institute for Manufacturing Engineering and Automation IPA were awarded the Otto von Guericke Prize for 2023 in recognition of their prospective solutions for coating technology. Both engineers, the two researchers studied ultra-precise and selective coating processes for an innovative method known as digital painting. Their method uses individual drops to create entire coats of paint and sharp lines, areas, or logos with hardly any overspray. The team studied coating properties to create drops and worked out specifications for paints and nozzles to be used in multi-color paint jobs, along with selective corrosion protection and complete elimination of overspray. A toolbox for paint producers and painting businesses presents their findings. Digital painting could add up to tremendous resource conservation and cost savings in practice, as less masking and clean-up work will be needed. The research prize, which comes with €10,000 in prize money, has been awarded by the German Federation of Industrial Research Associations (Arbeitsgemeinschaft industrieller Forschungsvereinigungen "Otto von Guericke" e.V.) since 1997. It is given out in recognition of particular innovations in precompetitive industrial collective research with public funding from the Federal Ministry for Economic Affairs and Climate Action (BMWK).

Thomas Hess and Franz Balluff from Fraunhofer IPA (third and fourth from left) received the award for sustainable painting processes

Photos: AiF e.V., Threedy

Sustainable Award in Automotive

Corporate consulting firm Arthur D. Little presented the third Sustainability Award in Automotive in 2023 in cooperation with Springer's professional publications focusing on automotive and engine technology. EDAG Engineering GmbH was recognized for its modular vehicle concept in the "Technology: Full Vehicle" category. The idea traces back to collaboration with the Fraunhofer Institute for Machine Tools and Forming Technology IWU. The goal of the joint project was to develop a vehicle platform for electric cars that is durable and offers protection in the event of a collision. The modular vehicle concept design makes it possible to replace individual components and reuse others multiple times. The judges pointed out that this extends the vehicle's life.

Science Prize for Operations Research

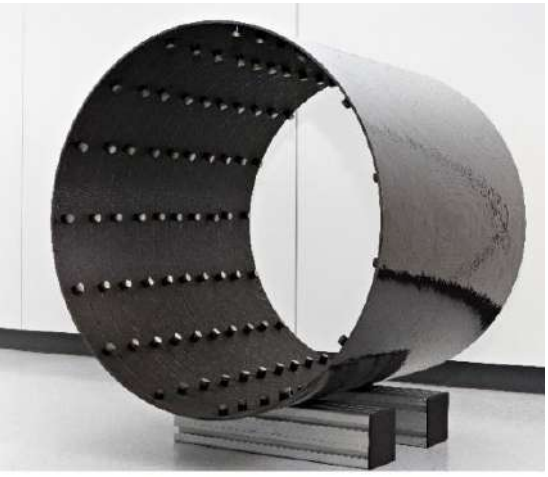
The German Operations Research Society (GOR) awards a science prize every two years. The prize for 2023 went to Prof. Anita Schöbel, head of the Fraunhofer Institute for Industrial Mathematics ITWM and a professor at the University of Kaiserslautern-Landau (RPTU). The field of operations research supplies mathematical models for decision making. Schöbel stressed that she wanted to raise the profile of these methods across society at large, government, and industry and pointed out that distribution of energy and planning of mobility are challenges that operations research can help with.

Prof. Anita Schöbel

Prof. Peter Liggesmeyer

German Prize for Software Quality

The German Prize for Software Quality for 2023 (DPSQ23) was awarded to Prof. Peter Liggesmeyer in June. Liggesmeyer, the head of the Fraunhofer Institute for Experimental Software Engineering IESE and holder of the chair of Software Engineering in the Department of Computer Science at the University of Kaiserslautern-Landau (RPTU), works on the topics of safety, security, reliability, and availability, particularly in the autonomous systems segment. The German Prize for Software Quality has now been awarded three times by the Working Group Software Quality and Training (ASQF), a specialist group of the German Informatics Society (GI-TAV), and the German Testing Board (GTB).



Vibro-acoustic metamaterials bring significant improvement in vibration behavior and are versatile in use

Best idea ever entered in INNOspace Masters competition

In 2023, the vibro-acoustic metamaterial (VAMM) technology from the Fraunhofer Institute for Structural Durability and System Reliability LBF was selected as the best idea from a research organization ever to have been submitted since the INNOspace Masters competition was first inaugurated, in 2015. The Fraunhofer LBF team has placed in the top three several times over the years. For example, Fraunhofer researchers began working with project partners MT Aerospace and OHB-System AG in 2017/18 to build three space demonstrators. Their work took the stresses involved in launching carrier rockets into account and showed how suitable the materials are for use in space. The findings of the Silent Running research project showed that VAMMs can be used in space and that the technology opens up new options for lightweight construction and vibration reduction. VAMMs contribute to lightweight construction solutions in the costly field of space systems, but that is not all. They also help to ensure that optical assemblies are not adversely affected by micro-vibration, so they can function without disruptions. Metamaterials display behaviors not found in nature. Along with optical and electromagnetic metamaterials, these kinds of materials can also be used to reduce noise and vibration.

Photos: Fraunhofer LBF / Ursula Raapke, Fraunhofer ITWM, Fraunhofer IESE / Matthias Heyde

Rising Digital Award for Logistikbude spin-off

Conciso, an IT company based in Dortmund, held its second round of awards for start-ups that unlock new benefits through digital transformation. Logistikbude, a spin-off of the Fraunhofer Institute for Material Flow and Logistics IML, won out over a number of prominent start-ups. The company organizes the management of pallets, containers, and various other reusable assets for companies. A Web-based solution and interfaces bring transparency to stock levels and flows, while coordination processes are automated. This kind of digital transformation of reusable management unlocks huge potential for resource conservation: according to Logistikbude, as much as 80 percent on staff, up to 40 percent on follow-up purchases, and up to 20,000 metric tons of carbon emissions. The start-up received €30,000 in prize money, along with several months of business development mentoring.

The founding team: Jan Möller, Dr. Philipp Hüning, Patrik Elfert and Michael Koscharnyj (from left)

German federal transport minister Volker Wissing presented the German Mobility Award to Dr. Claus Doll (Fraunhofer ISI), Nina Rösner (takomat GmbH), and Michael König (KIT) (from left)

German Mobility Award

The MobileCityGame research project, featuring the MobileCity app simulator, received the German Mobility Award in the "Digital Transformation & Data Driven Mobility" category. The app makes complex interrelationships in traffic and transportation systems understandable in an engaging way and serves as a visual aid for mobility models in contexts such as teaching or participatory processes. The team also developed a professional simulation tool for research and municipal mobility planning to develop sustainable and affordable mobility systems. The app is based on various simulation and analysis models, expertise, and data from the city of Karlsruhe. It is the only app in the world in which a complete traffic and transportation model runs locally on digital devices. Through their successor project, CarGoNE-City, the consortium plans to extend the simulation to urban logistics and translate it to three European cities. The app has been used in a seminar at Karlsruhe Institute of Technology (KIT) since the winter semester of 2023/24. The 30-person project team comprised researchers from the Fraunhofer Institutes for Systems and Innovation Research ISI and for Optronics, System Technologies and Image Exploitation IOSB, KIT, and takomat GmbH. The German Mobility Award is presented annually by the German Federal Ministry for Digital and Transport (BMDV).

Photos: Logistikbude GmbH, M. Golejewski

People in research

“The transformation of the energy system over the next two decades will be based mainly on technologies that are fairly well known today.”

Photos: Fraunhofer / Mike Abmaier, iStock.com/onurdongel

Prof. Mario Ragwitz

Joint Director of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG | Professor of Integrated Energy Infrastructures at Brandenburg University of Technology Cottbus-Senftenberg | Part-Time Professor at the Robert Schuman Centre for Advanced Studies, European University Institute | Honorary Professor at the University of Freiburg

Transformative technologies

High praise indeed: "Hiring Mario Ragwitz was the best thing | ever did for Fraunhofer," says Prof. Harald Bradtke, Ragwitz's first boss at the Fraunhofer Institute for Systems and Innovation Research ISI. Ragwitz moved from the Max Planck Institute for the Physics of Complex Systems to Fraunhofer ISI in 2002, bringing with him the very latest discoveries in mathematical chaos theory for the modeling of climate-neutral energy systems. Today, Ragwitz is one of Germany's leading energy system experts. What drives him?

"We need to mitigate the impacts of climate change if we are to survive. That means transforming the energy system is a necessity." One of the key factors in his decision to apply for a position at Fraunhofer was that his research would be able to have an impact in the real world — applied research, in other words. In 2023, some 21 years on, Ragwitz and Prof. Rolf Bracke serve as joint directors of the Fraunhofer Research Institution for Energy Infrastructures and Geothermal Systems IEG. He has been the spokesperson of the Fraunhofer Hydrogen Network since 2020 and the coordinator of the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES since 2019. In addition to the German federal government, he also advises the European Commission and the EU Parliament, the German Bundestag, the World Bank, the governments of other countries — and companies as well, of course.

Ragwitz says one of the key steps in the scientific success and trust in the reliability and robustness of his models was a 2004 study performed for the European Commission. "FORRES 2020: Analysis of the Renewable Energy Sources' Evolution up to 2020" already presented an analysis showing that the EU would not manage to reach its goals for the proportion of the energy supply derived from renewable sources by 2020 unless it ramped up its efforts. Ragwitz's subsequent activities included helping to identify the EU's renewable energy targets for 2020 and 2030. He was also involved in evaluating and further developing the Renewable Energy Sources Act in Germany.

Which technologies does Germany depend on in bringing about a fast, safe transformation of its energy system? Expansion of a flexible energy network across the electricity, gas, heating, and mobility sectors? Development of the hydrogen sector, including electrolyzers and retooling gas lines? Storage technologies like pit thermal energy storage and the scale-up of heat pumps to megawatt-hour capacity? Or expansion of geothermal systems, deep or near the surface, depending on suitability? There are questions and more questions, and they sound like there are too many unknowns. Ragwitz counters: "The transformation of the energy system over the next two decades will be based mainly on technologies that are fairly well known today and have proven that they work on a fundamental level." Those who would like to see for themselves can check out the Fraunhofer IEG locations, which are located in Germany's lignite-producing (or former lignite-producing) areas. Ragwitz believes that 90 percent of Germany's electricity can come from renewable sources if demand doubles between now and 2035 — and at reasonable cost, to boot. "I'm confident that we will be able to stabilize a price level that permits competitiveness, even taking into account carbon emission taxes, within a decade."

Prof. Liliana da Silva Ferreira

Computer Scientist | Member of the Executive Board of Associação Fraunhofer Portugal Research | Director of the Fraunhofer Center for Assistive Information and Communication Solutions AICOS, Porto | Invited Full Professor at the Faculty of Engineering, University of Porto

Returning to excellent research conditions

Prof. Liliana da Silva Ferreira led what is now the largest independent foreign Fraunhofer affiliate in Europe, the Associação Fraunhofer Portugal Research (or Fraunhofer Portugal for short), from 2017 until the end of November 2023. The first Center for Assistive Information and Communication Solutions AICOS was created in her hometown, Porto, under the umbrella of the newly formed nonprofit Fraunhofer Portugal in 2008, and Ferreira joined in the role of senior scientist not long after, in 2011. Her doctorate, which dealt with automated information extraction for medical reports, was an excellent fit for the topics covered by the new research institution. The subject was very current then, as it is now. Natural language processing (NLP) is a subfield of artificial intelligence (AI). While NLP relates to the analysis of natural language by computers, human-like content can now be produced by generative AI, such as ChatGPT.

Ferreira accepted an offer from an industrial group in 2016 and moved to the Netherlands with her family, including her children, who were small at the time. An insight came to her while working on the other side of the development and transfer equation: "It wasn't until | worked in development on the industry side that | realized that we at Fraunhofer AICOS were already operating at the highest international level in terms of science, right up there with top industry players." That realization has stayed with her to this day, giving her fresh drive. In 2017, Ferreira returned with her family — to Porto, and to Fraunhofer. The reason was that the Portuguese research ministry was planning to build another Fraunhofer center. Its themes were to be water and resource management. Both are pressing issues that demand solutions in Portugal, as they are across the whole of southern Europe. The populace and economy alike are already greatly suffering from the effects of climate change; one ministry employee Ferreira negotiated with about the Portuguese part of the base funding went without running water at home for several weeks in December 2017 — which should actually be the season when Portugal's many reservoirs are refilling. Ferreira brought a number of partners on board to develop the second Fraunhofer Portugal Center, especially the National Foundation of Science and Technology, the University of Évora, and the University of Trás-os-Montes and Alto Douro. Another objective was to raise funds for equipment and infrastructure for the Center for Advanced Water, Energy and Resource Management.

Her move to become the President of the Executive Board of Associação Fraunhofer Portugal Research marked a definitive shift for Ferreira as she transitioned from science to research management. She was able to present impressive figures during the successful evaluation of Fraunhofer AICOS in October 2023: External project revenue rose from €1.91 million in 2018 to a projected €3.84 million for 2023. Fraunhofer AICOS has been involved in 19 EU projects since it was first founded. It maintains partnerships with over 400 organizations in 37 countries and has been granted 18 patents based on the 38 applications filed to date. The head of Fraunhofer Portugal was awarded the Fraunhofer Thaler at the internal International Day event in 2023 in recognition of her years of work in various positions.

Ferreira stepped down as executive board president at the end of 2023. She has remained a board member and will be focusing more on Fraunhofer AICOS in her role as its director going forward. She was succeeded as the President of the Executive Board of Associação Fraunhofer Portugal Research by Pedro Almeida. Ferreira is happy to be moving back to a familiar range of duties, as it will give her an opportunity to work with her team as a computer scientist, creating digital applications that benefit humanity in line with the motto "Proposing Futures. Impacting Lives."

"It wasn't until | worked in development on the industry side that | realized that we at Fraunhofer AICOS were already operating at the highest international level in terms of science, right up there with top industry players. That realization has stayed with me to this day, giving me fresh drive."

Photos: Fraunhofer / João Macedo, iStock.com/mediterraneanan

“Transdisciplinary research will not only make it possible to achieve a sustainability transformation across society, but also to bring more young people into the study of engineering with social science aspects in the future.”

Dr. Dominik Spancken

Metalworker | Mechanical Engineer | Plastics Engineer

First Doctor of Sustainability

Germany's very first doctorate in sustainability has been awarded. The proud recipient of the new title is Dominik Spancken, team leader for resource-efficient composites at the Fraunhofer Institute for Structural Durability and System Reliability LBF. Darmstadt University of Applied Sciences is the first and only institution in Germany to date to offer a doctorate in sustainability sciences. Spancken, an engineer, defended his dissertation in July 2023, and it was published in November. He studied how conventional plastics used in major appliances such as dishwashers or washing machines can be replaced with recycled plastics. As a demonstrator, he chose the interior base of these kinds of appliances — components that consumers don't see because they are tucked away behind the paneling, but are subject to heavy wear. The potential in this area is impressive: If the entire interior base, which weighs about two kilograms, were made from recycled plastic instead of new plastic, annual consumption of crude oil for a production level of about three million dishwashers would drop by some 2,500 metric tons and carbon emissions by 7,800 metric tons. Aside from these possibilities, Spancken also analyzed the obstacles that stand in the way of industry switching to more sustainable plastics. They include the cost of recycled plastic, which is still slightly higher, along with the fact that conventional plastics still have better and more reliable availability. But Spancken firmly believes a rethink is possible: "Transdisciplinary research will not only make it possible to achieve a sustainability transformation across society, but also to bring more young people into the study of engineering with social science aspects in the future."

Spancken learned early on to forge his own path. Before earning his doctorate in sustainability sciences, he started out as an apprentice mechanic. He then took the exams to move back into academia and ended up studying mechanical engineering. Spancken is a marathoner, so he knows what endurance training is like. He was supported by his professional network. Prof. Andreas Büter, a department head at Fraunhofer LBF who teaches at Darmstadt University of Applied Sciences and RWTH Aachen University, brought Spancken to work at Fraunhofer LBF, first as a student and then, starting in 2011, as a scientist. He also supervised his doctoral studies. Multiple potential applications were considered with customer BSH, a major appliance producer, in 2020. The breakthrough came quickly: "We came up with the idea of recycled plastics in major appliances on a Friday. The plan and concept were in place by Monday, and we hit the ground running on Tuesday!" Robert Bosch GmbH and BSH provided €150,000 in funding for material studies as part of the dissertation. Spancken is currently working on behalf of Robert Bosch GmbH on material databases to make product development more efficient and reliable.

What is the runner's objective? In the long term, plastics expert Spancken would like to see a closer connection between engineering and social and cultural studies, including in formal instructional settings. He thinks industry and consumers need to develop an awareness of the resources used, including questions of what is really needed, costs, and flawlessness. Spancken is not alone in his efforts: A draft regulation put forward by the European Commission calls for cars to be made of 25 percent recycled materials starting in 2030.

Katrin Klug

Data Scientist | Business Analytics | International Business | Marketing and Commercial Distribution

The move to generative AI

From business and economics in aviation to a hotspot of generative artificial intelligence: Katrin Klug worked as a data scientist at Germanwings, then the International Air Transport Association in Montreal, and then Eurowings before making a change in 2020. She had already worked with applications and solutions relating to various aspects of data analysis when writing her master's thesis at Hochschule Düsseldorf University of Applied Sciences. At that time, she developed an AI forecast model for Eurowings Technik GmbH to predict flight delays and cancellations, which provided effective support for fleet management purposes. Her work paid off, and Klug received a special award in 2020. Verein der Förderer des Fachbereichs Wirtschaftswissenschaften der Hochschule Düsseldorf e.V., a nonprofit association of supporters of the business school at her university, praised her model's outstanding practical relevance.

Klug applied to work as a data scientist at Fraunhofer IAIS later that year. Her first assignment was to advance knowledge and technology transfer for artificial intelligence (AI). To that end, she set up a blog on machine learning (ML) and AI named the "ML-Blog." Researchers from the Fraunhofer Institutes for Intelligent Analysis and Information Systems IAIS and for Material Flow and Logistics IML, the University of Bonn, and TU Dortmund University all write posts there under the umbrella of the Lamarr Institute. Writing for the general public and companies alike, they explain the innovative potential of AI in robotics and illustrate what generative AI (GenAI) is all about and how it can be used. Their work is so accessible that media outlets such as heise have reported on it.

These days, Klug assists companies in making the move to AI — from testing research findings through to successful implementation. She developed the "GenAI Campus" collaboration format at Fraunhofer IAIS to support these activities. These several-day workshops bring employees of private enterprises together with scientists for close cooperation. Together, they take a deep dive into the fundamentals and potential applications of generative AI. The goal is to develop concrete use cases with the companies and test various foundation models or AI language models directly. The workshop concludes with a proof of concept, ideally followed by joint technological development. A GenAI Campus event is also a forum for questions surrounding the trustworthiness of AI — the famed "black box" question — and its limitations, such as hallucinations.

"We show how effective artificial intelligence can be in making people's day-to-day work easier. With our support, companies can dive into the new technologies very quickly, try them out, and gauge their benefits and suitability for their use cases. Those could be anything from form assistance features for administration and analytical tools for the financial industry to smart purchasing and quote management," says Klug, who, as an AI expert, now works as a project manager and instructor within the Fraunhofer Big Data AI Alliance training program.

She is also participating in the work to generate doctor's letters automatically via generative AI as part of the KI.NRW flagship project SmartHospital.NRW (see p. 52). Around 150 million doctor's letters are written every year in Germany. This takes precious time which could be used elsewhere. "Studies show," Klug says, "that healthcare professionals in clinical settings spend three hours a day on administrative tasks. That's three hours that could be used for patient care instead if generative AI takes care of those tasks."

“We show how effective artificial intelligence can be in making people’s day-to-day work easier and how much potential it can unlock. | really enjoy discovering this together with companies.”

Photos: Fraunhofer IAIS, iStock.com/monsitj

"Safely crushing melted radioactive material at Chernobyl to collect it for interim storage is a challenge that no one has solved so far."

Photos: Fraunhofer IWS, iStock.com/Saharrr

Oleksandr Proskurin

Engineer | In early 2023, Oleksandr Proskurin moved from Kyiv to Dresden, where the robotics expert spent six months at the Fraunhofer Institute for Material and Beam Technology IWS. His stay was funded as a pilot project by the new Rebuilding Ukraine program from the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation).

Pooling expertise for dismantling nuclear power plants (NPPs)

Like many members of his family, Oleksandr Proskurin is originally from Kherson, which has been heavily damaged in the war with Russia. While a student at the Kyiv Polytechnic Institute, he specialized in dynamics and machine strength. During this period, he completed several internships, including periods at the design office of the Ukrainian aircraft manufacturer Antonov and at the Chinese company Xianchu. Since completing his master's degree in 2015, Proskurin has been conducting research on robotic applications in nuclear situations at the Institute for Safety Problems of Nuclear Power Plants (ISPNPP). The institute forms part of the National Academy of Sciences of Ukraine.

It was Dr. Andreas Wetzig who convinced Proskurin to join his host team in Dresden. In his role as head of the technology field for Cutting and Joining at Fraunhofer IWS, he has been establishing contacts to companies and organizations in the NPP decommissioning sector since 2016. Wetzig and his team see great potential for the use of laser technology in this field since laser cutting generates very little dust when disassembling contaminated materials, unlike other technologies. All of the material, not just contaminated construction and nuclear material, needs to be collected before it can be sent to decay in interim storage facilities. At any rate, as Wetzig and Proskurin are aware along with others, the global community has less than 100 years to find a solution. That is when the second sarcophagus, which was moved into place atop the ruined nuclear facility in Chernobyl along a set of purpose-built tracks in 2016, will no longer be able to contain the radiation from the fuel core, which has melted down into lava. Robot and laser researchers share a common goal: remotely control laser robots to crush the baked radioactive material and prepare it for interim storage. They also tested the cutting of basalt as a substitute substance for the fused radioactive material in the Fraunhofer IWS laser laboratories. "Safely crushing melted radioactive material at Chernobyl to collect it for interim storage is a challenge that no one has solved so far," says the robotics expert, who hopes that their collaboration will continue.

In July 2023, Oleksandr Proskurin returned to Kyiv, where he is living and working today. He tries to find distraction from the war and the frequent air raids through DIY activities and sports — from (table) tennis to bike tours. In August 2023, he attended a radiation safety seminar in Slavutych, a satellite city of Chernobyl. It is considered a global research site for safety and decommissioning issues related to nuclear energy.

Rebuilding Ukraine

The new funding program from the Fraunhofer-Zukunftsstiftung (Fraunhofer Future Foundation) promotes collaborative efforts for applying Fraunhofer technology in Ukraine. The program's current objective is early planning for the repair of war damage in Ukraine and preparing for reconstruction using technologies that are sustainable. Oleksandr Proskurin was the first visiting scholar whose stay was co-funded as a pilot project through Rebuilding Ukraine.

Dr. Eva Ehrentreich-Förster

Chemist | Deputy Head of the Bioanalytics and Bioprocesses Institute Branch at the Potsdam-Golm Site of the Fraunhofer Institute for Cell Therapy and Immunology IZI | Head of the Department of Molecular and Cellular Bioanalytics

Diagnostics as a special case in analytics

Eva Ehrentreich-Förster officially graduated in chemistry at TU Bergakademie Freiberg, in what was then East Germany, on November 9, 1989, the very day the country opened its borders. She didn't end up joining the throngs crossing to the west the day the Berlin Wall came down, since she was happy just to get home amid the transit chaos following her graduation ceremony. But her decades of work as a researcher after that would often see her straddling the line between different worlds: transcending disciplines as a project manager for lab-on-a-chip systems, navigating between the institute and executive board perspectives as an elected representative of the scientific and technical council at Fraunhofer, and in the role of acting institute director until just recently. Prof. Antje Bäumner stepped in as institute director in August 2023, heading the Brandenburg part of the Fraunhofer Institute for Cell Therapy and Immunology IZI. Ehrentreich-Förster has been happy to go back to her position as deputy institute director and department head. "The more challenging my tasks became as | moved through my career from young researcher to acting director, the more | went running," she says. A former heptathlete, Ehrentreich-Förster still runs long distances.

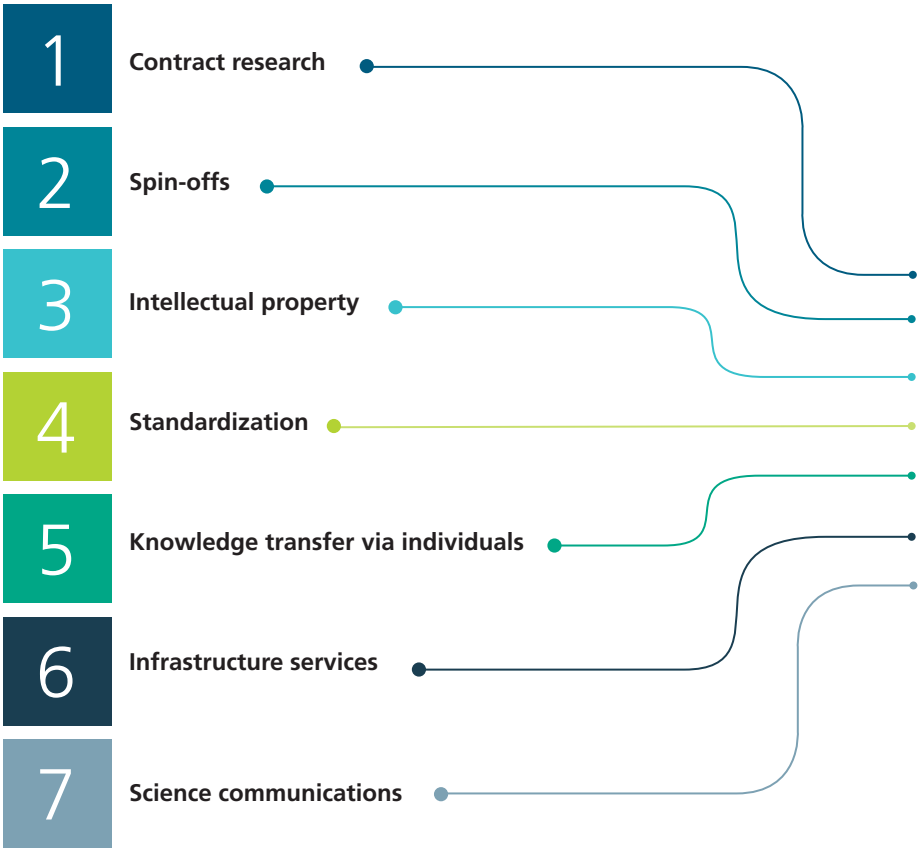
Ehrentreich-Förster's research field is microarrays, bioanalytical platforms for diagnostic purposes — whether for foods, the environment, or people. "Knowledge of sensors, evidence of the formation of a bond, has been with me since | got my degree," she says. After earning her secondary school diploma, she worked first in the lab at the Graupa Product Toxicology Research Center. She was recommended for the chemical degree study program by her boss. She went on to postgraduate studies in toxicology at the University of Leipzig and then received a German Academic Exchange Service (DAAD) fellowship to go to the University of Córdoba during her doctoral studies. Her first role as a research scientist was at the Max Delbrück Center for Molecular Medicine. She then moved on to the University of Potsdam before joining Fraunhofer with her junior research group as part of a German Federal Ministry of Education and Research (BMBF) competition, initially working at a branch lab. "I was so proud to get the job," she recalls. She also remembers how tough the first few years were: "There's a mindset that goes into doing research like a scientific company, and you have to learn that first. It's not something you cover in grad school." There was also a certain amount of cultural adjustment involved, as Ehrentreich-Förster had to become acquainted with both general public-sector guidelines and the freedom to design her own research topics.

Ehrentreich-Förster moved on to managing internal Fraunhofer interdisciplinary funding projects relating to the in-vitro diagnostics platform, and she was instrumental in the 2014 presentation of the very first "Taschentuchlabor" (Lab in a Hankie) for infection diagnosis, which was the result of a project funded by the BMBF. Research findings like these have continued to flow to the Fraunhofer Center for Digital Diagnostics in Potsdam, which was founded in 2021. Within the center, the Fraunhofer Institutes for Cell Therapy and Immunology IZI and for Experimental Software Engineering IESE work together under the leadership of the Bioanalytics and Bioprocesses branch of Fraunhofer IZI to advance medical and diagnostic care in rural areas like Brandenburg. The goal is to provide patients with good medical care now and into the future, despite the lack of general practitioners in private practice and the cost pressure affecting the healthcare system. For that to happen, however, there are some regulatory obstacles in the field of medicine that need to be overcome: equipment approvals as well as data protection and privacy solutions. Ehrentreich-Förster has been working on platforms that can automate analysis and — if the approval process goes smoothly — diagnosis as well. She is familiar with costs and affordability as factors. And she wonders whether greater funding should be put into certain questions. "Everyone knows about antibiotic resistance, and everyone also knows that very little research is being funded in this area worldwide. Health should be for everyone!"

"Health should be for everyone!"

Photos: Fraunhofer IZI-BB / Martina Steude

Selected transfer activities



Impact on industry and society

Fraunhofer customers commercialize more innovations 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

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

The efforts that Germany's non-university research institutions put into strengthening the country's industry and society are transmitted along seven transfer paths. 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 2023
€679 million from industry contracts (within Germany and international, excluding license-fee revenue)

Investigational medicinal products for cancer treatment using live cells
In Europe, all innovative medications are first tested in clinical trials involving selected patients before they are approved for widespread use. These investigational medicinal products must be produced according to stringent pharmaceutical quality standards (good manufacturing practice, or GMP). That is a complex undertaking for innovative cell and gene therapies like chimeric antigen receptor (CAR) T-cell therapy, an advanced form of cancer treatment, since these therapies are based on living cells taken from patients. The cells cannot be standardized, and their condition depends on the specific patient's disease and past treatments. Processes and technologies must be developed to balance the requirements and the starting basis for GMP standards. The GMP Cell and Gene Therapy department at the Fraunhofer Institute for Cell Therapy and Immunology IZI specializes in tasks like this. The institute's GMP facilities have been manufacturing what are known as CAR T-cell therapeutics for more than ten years. These are investigated in clinical studies and followed through to approval. In 2023, Fraunhofer IZI received a contract from an international pharmaceutical company for technology transfer and validation of the manufacturing process for a new CAR T-cell therapy. All process steps, including quality control, must be aligned to Europe's high quality standards in order to obtain manufacturing authorization pursuant to section 13 of the German Medicinal Products Act (Arzneimittelgesetz, AMG). Afterward, all of the investigational medicinal products for the study — which involves numerous medical centers around Europe — are produced in Fraunhofer IZI's cleanroom facilities.

2. Spin-offs

Key figures for 2023
23 spin-offs
1 shareholding

Tapping the power of sunflowers
How can food proteins be produced from sunflower seeds as a form of sustainable nutrition? Over a 20-year period, specialists at the Fraunhofer Institute for Process Engineering and Packaging IVV developed a method of producing a high-quality protein ingredient from shelled sunflower seeds. First, a mechanical process removes the oil, which increases the seeds' protein content as compared to seeds that do not undergo this process, without harming the protein itself through factors such as exposure to high temperatures. Then the remaining oil is extracted using solvents, a process that also leaves the seeds intact. The team of researchers found a way to use ethanol instead of hexane, a petroleum derivative commonly used for these purposes. Ethanol is a green product that can be derived from renewable raw materials. After the product and method were patented, Sunbloom Proteins GmbH was spun off from Fraunhofer IVV in 2017. Zentis was brought in as an investor in 2019, and leading dairy firm Molkerei Ehrmann joined not long afterward. In cooperation with these partners, the company opened its own plant in Drégelypalánk, Hungary, in 2022. The new plant can produce the protein concentrate, which has great nutritional and functional benefits, for foods at an industrial scale. In 2023, Sunbloom Proteins GmbH was sold to the Avril Group, which is based in France. The Fraunhofer spin-off has now added its sustainability technology to the expertise portfolio of one of the leading industrial and financial players in the plant oil and protein segment.

3. Intellectual property

Key figures for 2023
€158 million in license-fee revenue
506 invention disclosures
7,068 active patent families
406 patent applications

DRYtraec®: a game changer in battery cell production
Previous methods of producing battery cells are energy-intensive and costly. When battery electrodes are produced, thin metal foils are coated with a wet paste of active material, conductive carbon black, binders, and solvents, some of them toxic. The subsequent drying of the electrode layer requires a lot of energy and space.

By contrast, the DRYtraec® dry coating technology developed by the Fraunhofer Institute for Material and Beam Technology IWS uses no toxic solvents at all. A special roller unit is used to mechanically anchor particles of the active material and conductive carbon black by causing the binder to form fibrils, a process known as fibrillation. This means the process of creating the electrode layer is entirely dry. Energy-intensive drying is eliminated, and both sides of the electrode can be coated at the same time. The process was first developed for electrodes in lithium-ion batteries and has now been adjusted for lithium-sulfur and solid-state batteries as well. The first prototype system of its kind in the world has been developed with German plant engineering firms. Fraunhofer IWS has operated a full-spectrum technology platform for dry coating with a high level of technological maturity since 2020. Fraunhofer IWS and the Fraunhofer Research Institution for Battery Cell Production FFB are currently planning a scaled pilot plant on the basis of the DRYtraec® method for installation in Münster. High-quality, low-cost production of battery storage is crucial to the electrification of the German automotive industry. However, Europe is still in the process of building production capacity for battery cells and remains highly dependent on technology groups based in Asia. The patented DRYtraec® technology developed by Fraunhofer IWS (EP 3625018, IWS – 2017F59214, patents granted in Europe, Japan, and Korea) can make a crucial contribution to greater cost efficiency and ecofriendliness in cell production in the future. A license agreement with a leading German automotive company was signed in 2023.

4. Standardization

Key figures for 2023
1,366 standardization activities

Clearing the way for the 5G wireless standard
Now in its fifth generation (5G), wireless technology has gone from voice telephony to the mobile internet and beyond, becoming a universal communication standard for linking sensors, devices, and machines. The technical specifications for this global standard are developed and adopted by the 3rd Generation Partnership Project (3GPP) and implemented as specifications by the standardization bodies in the relevant areas. During the time between when new functions are defined in the wireless standard and when they become available on the market, it is nearly impossible to test future applications for lack of suitable test environments and detailed knowledge based on ongoing standardization. This means closing these kinds of gaps between research, standardization, and application is crucial to rapid market entry. The Fraunhofer Institutes for Telecommunications, Heinrich-Hertz-Institut, HHI and for Integrated Circuits IIS have been involved in defining and further developing this important wireless technology since 2015, when 3GPP began working on the 5G specifications. They made over 900 contributions to the 5G standard between 2015 and 2023. Parallel participation in relevant industry bodies such as NGMN, 5GAA, and 5G-ACIA supports Germany's industry in incorporating key requirements and functions into the standard, which in turn is a requirement for implementation in the mobile network and devices. The focus is on the radio access network (RAN). In their work, the institutes have come to concentrate on professional applications in the area of the internet of things (IoT), satellite integration into mobile networks, production automation, and connected vehicles (V2X).

5. Knowledge transfer via individuals

5.1 Continuing professional development for external specialists and managers

Key figures for 2023
Over €10 million in revenue from Fraunhofer Academy professional development courses
Approx. 6,600 participants in 600 courses

Customized training for companies
Since 2018, the Fraunhofer Institute for Material Flow and Logistics IML has been helping Interroll Holding GmbH to meet its employees where they are in terms of knowledge transfer relating to logistical issues. Interroll Holding GmbH is a provider of conveyor technology and an international listed company with some 2,500 employees. Its customers are equipment manufacturers, engineering firms, or system integrators. The company has adopted a sales approach known as consultative selling. To do this effectively, sales and marketing employees need to know how innovations in logistics and intralogistics affect process organization on the end customer's side so they can use those innovations to explore new projects. A course titled Process Management imparts current knowledge of the intralogistics market, future trends, and industry-specific know-how. The specialists from Fraunhofer IML contribute their knowledge of the intralogistics market in particular, including the latest planning tools. The course is now in its eighth cycle, which involves blended learning in the form of short webinars and supervised group work. Theoretical base content is combined with practical simulations and on-site visits to end customers. Pre-learning activities and context-specific follow-ups have also been incorporated into the overall concept to ensure that participants retain the understanding of the system that is taught in the course.

5.2 Employees and careers

Key figures for 2023
Some 2,200 people left Fraunhofer to continue their careers — in industry or the research sector or by starting their own company.

Training for positions of responsibility
One key aspect of Fraunhofer's mission is the training phase that scientific staff in particular complete during their period of employment with Fraunhofer. Fraunhofer had a 9.9 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. Approximately 70 percent of these departing employees said they were moving on to roles in industry.

Jobs and careers at Fraunhofer

6. Infrastructure services

Key figures for 2023
No figures are available in this area (yet). These can currently be seen in other transfer paths.

Intelligent sensors for the energy transition
The Intelligent Signal Analysis and Assistance Systems InSignA high-performance center was founded in Ilmenau in 2021 as one of Fraunhofer's most recent high-performance centers. Five Fraunhofer institutes are involved, along with TU Ilmenau and IMMS Institut für Mikroelektronik- und Mechatronik-Systeme gGmbH, which is based in the German state of Thuringia. One of InSignA's core competencies is the development of low power wide area networks (LPWANs). Compared to technologies like 5G, the mioty® LPWAN standard that the Fraunhofer Institute for Integrated Circuits IIS was instrumental in developing enables the development of much lower-cost networks with a battery life of over a decade. In addition, practically no infrastructure is needed, so mioty® can be used even in areas with inadequate mobile coverage. Together, the high-performance center's partners built a test bed for LPWAN in Ilmenau, with support for various transmission systems. A study conducted with local utility company Stadtwerke Ilmenau, for example, focused on supporting the energy transition: Can a solar array, charging station, or heat pump still be connected to the power grid when a new building is being built or an old one renovated, or would that be enough to overload the grid? In partnership with Stadtwerke Ilmenau, the InSignA high-performance center was able to show that mioty® allows for development of very low-cost, easily installed retrofit sensors. In this kind of retrofit, new sensors are built into existing buildings to get them ready for the requirements of the digital transformation and Industry 4.0. The LPWAN test bed gives Stadtwerke Ilmenau a way to detect potential grid overloading early on during the process of approving new sources or consumers of electricity. This has generated significant added value in Ilmenau for many of those involved in the energy transition: private individuals, municipalities, and manufacturers of these kinds of equipment.

7. Science communications

Key figures for 2023
According to a media engagement analysis, Fraunhofer appeared in 10,991 articles; of these, 62 percent were initiated by Fraunhofer itself. They were viewed 6.050 billion times.

Into the universe with Fraunhofer AVIATION & SPACE
"Our Universe" was the theme of Science Year 2023 in Germany. Fraunhofer researchers supported the initiative sponsored by the German Federal Ministry of Education and Research (BMBF) with numerous public formats and exhibits. The activities were coordinated by the Fraunhofer Aviation and Space Alliance and the central Public Formats and Initiatives department. On average, half of all missions conducted by the European Space Agency (ESA) in the past 20 years had Fraunhofer developments on board. During the science year and beyond, a number of spectacular developments have been and continue to be involved in space missions. Back in 2020, Fraunhofer delivered the GESTRA radar system to the German Aerospace Center (DLR) to improve monitoring of low Earth orbit for risks posed by space junk. The metal mirrors for the Mid-Infrared Instrument (MIRI) used in the James Webb Space Telescope, which transmits images of unprecedented quality, come from Fraunhofer. So does the imaging spectrometer used in the EnMAP mission. The LisR infrared camera module proved its value on board the International Space Station (ISS) in 2023, and the ERNST small satellite is scheduled to launch in 2024. For Fraunhofer, the highlight of Science Year 2023 was an exhibit titled "Down to Earth Space Technology," held at the Fraunhofer Forum Berlin in early May. In various formats, scientists talked with young people and adults about subjects such as how advanced space technologies can help to deepen our understanding of climate change and its impacts, identify environmental degradation and pollution, protect critical infrastructure, and make agricultural water use more sustainable.

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.

Initiatives

Generative artificial intelligence

Research on, as well as the development and availability of, generative AI models and resulting applications such as chatbots already represent key competitive factors today. The use of these models is expected to have a major influence on the digital transformation and make an even greater contribution to gross value added in the future. Fraunhofer institutes have been driving these trends in various fields for years now. For example, the OpenGPT-X initiative has created large European language models. As of 2023, the Fraunhofer intranet offers all employees access to FhGenie, an adapted internal model based on ChatGPT 3.5. The "Learning Systems and Cognitive Robotics" AI innovative center in Stuttgart helps companies unlock the economic opportunities offered by AI, especially machine learning, in applied research projects. In the summer of 2023, Fraunhofer published a concept paper titled "Analysis and Recommendations on the Subject of Language Models and Generative AI" (*Analyse und Handlungsempfehlungen zum Thema Sprachmodelle und Generative KI*). It recommends a three-step approach: access, adapt, and advance. The goal is to build in-depth expertise and a custom-fitted range of solutions for the use of generative AI across industry and the research sector. Access to large volumes of high-quality training data is a key prerequisite for this. The challenge after that is to link models with reliable fact checks, accurate and reliable sourcing, and data control, especially for industrial applications. The paper also includes suggestions for training AI specialists. Joint strategies with German and European partners could offer advantages, especially when it comes to the costly process of training foundation models. Fraunhofer is also involved with the draft EU Artificial Intelligence Act (AIA), which aims to create a shared regulatory and legal framework for AI.

Raw material transition and bioeconomy roadmap

In light of its strategic raw material dependence, the EU is increasingly focusing on bringing about a rapid transition in raw materials. Fraunhofer's research and innovation activities are making a critical contribution to this. Fraunhofer is a co-founder of the Advanced Materials Initiative 2030 (AMI2030), which serves as an integrative forum for research and innovation in this field. Subject to the approval of the Member States, the initiative is expected to yield a partnership within the Horizon Europe framework program in early 2024 to place this topic on the European research and innovation agenda on a long-term basis. Fraunhofer's new ORCHESTER flagship project is blazing a trail in this regard with the objective of providing reliable and safe materials for the energy transition along the entire value chain. At the same time, Fraunhofer's circular bioeconomy roadmap is helping to enable innovative methods and products, new business models, and value creation networks for sustainable and resource-efficient economic activity. The roadmap was presented in September 2023 by the Fraunhofer EU Office in Brussels and the Fraunhofer Strategic Research Field Bioeconomy at a high-profile event involving the European Commission.

Energy partnerships

The Fraunhofer Representative Office Korea organized the fourth Germany-Korea Hydrogen Conference in late fall 2023. The Fraunhofer representative office was supported in these activities by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) and the German Federal Ministry of Education and Research (BMBF). The energy partnership between Korea and Germany has existed since 2019. With over 230 participants, the purely analog conference set a new record for attendance, drawing a large proportion of industry participants and high-ranking government officials from both countries. Multiple Fraunhofer institutes contributed to the program. With four future Fraunhofer innovation platforms and two ICON collaborations, Korea is an especially desirable target country for international strategic research collaborations.

Also in late fall, the Fraunhofer Cluster of Excellence Integrated Energy Systems CINES and consulting firm GHD Advisory published the National Hydrogen Strategy of the United Arab Emirates (UAE). Fraunhofer CINES and GHD Advisory had

been commissioned to draft the strategy as part of Germany's energy partnership with the UAE. The UAE is striving to become one of the world's biggest producers of hydrogen by 2031. Demand for hydrogen is expected to be significant, both domestically and for export. With an eye to a defossilized future, the team of authors from Fraunhofer CINES and GHD Advisory conclude that the UAE's low-carbon hydrogen production capacity could reach 7.5 million metric tons per year by 2040 and nearly 15 million by 2050. The goal of the strategy is to develop long-term measures based on the analysis for a sustainable energy policy and to attract additional investment to this area.

Fusion research — a clean energy source of the future?

Research groups all over the world are working to explore new emission-free sources of energy. One promising possibility lies in the fusion of hydrogen atoms to form helium in magnetically enclosed fusion plasmas. The Wendelstein 7-X stellarator-type fusion device at the Max Planck Institute for Plasma Physics, for example, is one of the world's leading large-scale devices in this field. Laser-driven inertial fusion energy (IFE) is another potential fusion source. A significant breakthrough in this area was made at the Lawrence Livermore National Laboratory in the United States in late 2022. Researchers demonstrated the physical feasibility of igniting a fusion plasma for the first time. This is a key requirement for realizing a fusion power plant. Much as with magnetic confinement fusion, there are already concepts for power plants based on IFE. Further technological advances over at least a decade will likely be needed before this can become a reality.

The German Federal Ministry of Education and Research (BMBF) founded an expert committee in 2023. It is being led by Prof. Constantin Häfner, executive director of the Fraunhofer Institute for Laser Technology ILT and Fraunhofer commissary for fusion energy. In a memorandum, the committee outlined issues and ways to realize an IFE power plant in technical terms. The memorandum is now being followed up internally by the German Federal Ministry of Education and Research (BMBF) with an eye to the key technologies needed to implement a power plant concept. A Fraunhofer task force brings together the available expertise in fusion research, including high-performance lasers, production of high-quality optics, technologies for targets and fuels, and technologies for development of reactor walls. One of the Fraunhofer-Gesellschaft's main goals is to empower industry to develop relevant key technologies in global competition.

Launching Fraunhofer flagship projects

AMMONVEKTOR — Green ammonia as a cross-sector vector for the energy transition

The Fraunhofer consortium is focusing on ammonia as an elementary building block of the hydrogen economy. Ammonia features better properties of storage and transport efficiency compared to hydrogen, thanks to its volumetric energy density. This makes it attractive as a carbon-free, economically viable hydrogen carrier to serve the immense industrial demand for electricity and process heat. This is especially true of medium-sized, energy-intensive companies that are threatening to relocate abroad due to high energy prices and will not be directly connected to a hydrogen pipeline in the future. Ammonia can be used in engine applications and in fuel cell cogeneration of heat and power, where it serves for decentralized power generation.

The project's development objectives will look at the entire value chain for ammonia as an energy vector. This includes developing reactors and catalysts for flexible, energy-efficient ammonia production, as well as technology for ammonia cracking on a small scale, in order to make pure hydrogen available on a decentralized basis. Storage and logistics systems for decentralized use of ammonia are also being created, and technical and financial analysis is being leveraged to develop new business models. These advances in technology will address the most significant hurdles to using ammonia as an energy vector (see p. 51).

ORCHESTER — ecosystem for a resilient and sustainable supply of materials

This research team is tackling the challenges of the circular economy and ensuring the security of the supply of materials. The focus is on resilience, sustainability, and reliable functioning of materials. The objective is to broaden the selection of materials through more-detailed knowledge of the interactions between chemistry, processes, microstructure, and properties. The researchers also aim to increase the percentage of materials being recycled by achieving better control of impurities in secondary metals and lowering the proportion of rare earths that are used in raw materials production, as these elements are critical from an origin standpoint. At the same time, they plan to move away from material specifications defined by the material composition and process route and toward function-based specifications instead. This will permit faster substitution of critical materials, enhancing the resilience of the supply.

The researchers plan to show this using components such as bipolar plates for electrolyzers and fuel cells, where costs are determined to a significant degree by the proportion of nickel. Nickel is a critical element; it faces significant supply risks and is also highly important in economic terms. In a crisis scenario, the proportion of nickel would need to be reduced without jeopardizing the plates' key functional properties. In the case of compressor wheels for hydrogen pipelines, fuel cells, and heat pumps, plans call for maximizing the secondary material proportion of the aluminum alloy to minimize the energy footprint. The researchers will also be looking at ways to recycle and reuse permanent magnets for applications in electric motors and wind turbines. Goals include using simulation models and machine learning to predict how material composition influences the effects of materials. ORCHESTER is leveraging the experience gleaned from existing initiatives such as Gaia-X and Materials Data Space® to build its own digital ecosystem.

Completed Fraunhofer flagship projects

EVOLOPRO — Evolutionary self-adaptation of complex production processes and products

Over 50 researchers from seven Fraunhofer institutes analyzed various evolutionary biology elements of flexibility and self-adaptation and applied their findings to production of complex components. These elements served as the basis for a new generation of "biological manufacturing systems" (BMSs). Like biological organisms, BMSs independently adjust to new requirements and environmental conditions — and, thanks to Industry 4.0 technologies and principles, they do it in just a short time. To that end, the researchers developed biologically inspired algorithms and digital twins that interact with a digital environment.

The concepts were validated in three pilot chains: Aviation, Optics, and Automotive. For milling blade-integrated disks, an innovative simulation environment was created on the basis of biologized algorithms, significantly reducing the time, effort, and expense that go into process planning and the insertion process. For production of complex glass optics, the team digitalized the entire manufacturing chain and developed a self-learning method for automated assembly of optical components. In the Automotive pilot chain, a model-based controlled body manufacturing system was established while tapping into the full potential offered by Industry 4.0.

A cloud-based data lake architecture was created to hold the huge volume of process data. It also provides standardized data interfaces and specific description models for unambiguous identification of the data uploaded. Building on the results, further research projects will continue to pursue the digital twin and digital environment concepts. The measures from the pilot chains are to be further developed specifically in the direction of market readiness for concrete use in industry.

Go to video

QMag — Quantum Magnetometry

Quantum magnetometers are highly sensitive sensors that can measure even the tiniest magnetic fields, so they offer tremendous potential for optimization of industrial processes. The consortium for the Qmag flagship project studied and developed quantum magnetometers. The researchers relied on two principles: nitrogen vacancy (NV) centers in diamonds, and optically pumped magnetometers. The two measurement methods are a perfect fit when it comes to achieving superior spatial resolution and extreme sensitivity.

The project team succeeded in developing customized measurement systems for various industrial applications. Especially in terms of material characterization, both types of sensors were used to achieve goals such as detecting microscopic damage in ferromagnetic materials. In the automotive and aerospace industries, these systems can help to make materials more resilient, safer, and more reliable. Quantum magnetometers can also be used in chip production to visualize the nanoscale magnetic fields of electronic circuits. The researchers also developed new measurement methods such as magnetometric flow measurement, which measures the speed at which fluids move through a pipe, and the long-range magnetometer for fast imaging measurements of large areas. These methods are suitable for applications in quality and process control and in biomedicine.

Go to video

For more information about completed Fraunhofer flagship projects, please see p. 47 (Production architecture for the factory of the future — SWAP) and p. 53 (Ensuring that treatments have optimum effects — MED²ICIN).

Finances

- Balance sheet at December 31, 2023
- Income statement for the financial year 2023
- Excerpts from the notes to the 2023 financial statements
- Convenience translation of the German independent auditor s report

Balance sheet at December 31, 2023

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

ASSETS	2023 in €	2023 in €	2023 in €	2022 in € (1,000)
A. Noncurrent assets				
I. Intangible assets				
1. Concessions, intellectual property rights and similar rights and assets	34,407,776.83			38,394
2. Advance payments	3,438,261.26			1,102
		37,846,038.09		39,496
II. Property, plant and equipment				
1. Land, land rights and buildings, including buildings on third-party land	1,597,243,700.26			1,596,631
2. Technical plant and machinery	603,033,050.60			597,863
3. Other plant, operating and business equipment	123,188,551.17			75,441
4. Advance payments and assets under construction	595,415,346.92			453,751
		2,918,880,648.95		2,723,686
III. Financial assets				
1. Shares in affiliated companies	92,782.82			93
2. Shareholdings	31,455,699.62			9,136
3. Securities held as noncurrent assets	8,238,664.30			8,239
4. Other loans	890,000.00			1,245
		40,677,146.74		18,713
			2,997,403,833.78	2,781,895
B. Current assets				
I. Inventories				
1. Raw, auxiliary and operating materials	41,502.79			102
2. Work in progress — 529,330,556.60				523,039
advance payments received –476,053,145.87				–404,279
	53,277,410.73			118,760
3. Advance payments	131,202.06			266
		53,450,115.58		119,128
II. Accounts receivable and other current assets				
1. Trade receivables	326,725,490.88			271,741
2. Receivables from the federal and state governments				
a) relating to base funding 374,260,757.04				27,835
b) relating to project billing, including contract research 354,808,691.19				335,161
c) relating to pension and compensated leave provisions 109,263,100.00				106,515
	838,332,548.23			469,511
3. Accounts receivable from affiliated companies	402,527.82			7,627
4. Other current assets	105,385,304.68			130,984
		1,270,845,871.61		879,863
III. Other securities		459,184,505.91		512,137
IV. Cash and cash equivalents		18,231,862.53		293,416
			1,801,712,355.63	1,804,544
C. Prepaid expenses and deferred charges			56,367,938.45	30,470
			4,855,484,127.86	**4,616,909**

Trust assets	83,371,518.07	65,669

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

EQUITY AND LIABILITIES	2023 in €	2023 in €	2023 in €	2022 in € (1,000)
A. Equity				
I. Non-profit organization capital				
Carried forward	15,525,289.24			15,453
Annual result	113,457.54			72
		15,638,746.78		15,525
II. Reserves for statutory purposes				
Carried forward	15,725.00			15
Transfers	5,000.00			–
Allocations	500.00			1
		11,225.00		16
			15,649,971.78	15,541
B. Extraordinary items				
1. License-fee revenue reserve for statutory purposes		372,237,826.83		404,402
2. Grants relating to noncurrent assets		2,986,183,710.74		2,770,535
3. Grants used to finance current assets		320,427,662.86		379,726
4. Extraordinary item for payments from patent sales		103,227,488.63		128,372
5. For financing restructuring measures		16,845,800.00		21,145
			3,798,922,489.06	3,704,180
C. Provisions				
1. Provisions for pensions and similar obligations		9,133,100.00		8,765
2. Other provisions		267,852,296.93		233,814
			276,985,396.93	242,579
D. Liabilities				
1. Trade payables		134,788,727.24		120,015
2. Unappropriated grants from the federal and state governments				
a) relating to base funding	392,113,362.54			319,916
b) relating to project billing	169,370,509.32			164,316
		561,483,871.86		484,232
3. Accounts payable to affiliated companies		1,070,579.63		769
4. Other liabilities		58,605,929.45		44,550
			755,949,108.18	649,566
E. Accrued expenses and deferred income			7,977,161.91	5,043
			4,855,484,127.86	**4,616,909**

Trust liabilities	83,371,518.07	65,669

Income statement for the financial year 2023

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

		2023 in €	2023 in €	2023 in €	2022 in € (1,000)
1.	**Revenue from base funding**				
1.1	Federal government		848,171,234.03		876,651
1.2	State governments		169,047,913.62		173,603
				1,017,219,147.65	1,050,254
2.	**Revenue from own activities**				
2.1	Revenue from research and development activities				
2.1.1	Federal government: Project funding	906,318,110.02			767,393
	Contracts	23,867,480.40			29,347
2.1.2	State governments: Project funding	240,105,627.32			265,358
	Contracts	4,927,691.62			9,913
2.1.3	Industry, business and trade associations	821,256,260.02			756,401
2.1.4	Research funding organizations and other sources	213,288,574.07			192,161
			2,209,763,743.45		2,020,573
2.2	Other revenue		7,194,496.20		6,706
Total revenue				2,216,958,239.65	2,027,279
2.3	Increase in work in progress (2022: decrease)		6,292,062.01		–3,990
2.4	Other internally constructed and capitalized assets		8,343,791.48		6,143
2.5	Other operating income		75,397,181.92		38,817
2.6	Income from shareholdings		8,099,776.33		12,058
2.7	Other interest and similar income		12,477,610.97		2,901
				110,610,422.71	55,929
Total of base funding and revenue from own activities				3,344,787,810.01	3,133,462
3.	**Change in extraordinary items**				
3.1	License-fee revenue reserve for statutory purposes				
3.1.1	Allocations		–		–23,821
3.1.2	Reversals		17,638,314.28		34,927
3.2	Grants relating to noncurrent assets				
3.2.1	Allocations (capital expenditure)		–579,967,938.87		–482,260
3.2.2	Reversals (depreciation and amortization)		378,835,088.44		345,822
3.3	Grants released from financing current assets (2022: grants used to finance current assets)		59,297,920.23		–84,233
3.4	For financing restructuring measures				
	Allocations		–		–46
	Reversals		4,298,900.00		3,512
				–119,897,715.92	–206,099
4.	**Total of base funding and revenue from own activities available to cover expenditure**			**3,224,890,094.09**	**2,927,363**

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

	2023 in €	2023 in €	2023 in €	2022 in € (1,000)
Carryover			3,224,890,094.09	2,927,363
5. Cost of materials				
5.1 Expenditure on raw, auxiliary and operating materials	256,735,492.34			197,204
5.2 Expenditure on purchased research and development services	270,404,409.89			241,061
		527,139,902.23		438,265
6. Personnel expenses				
6.1 Salaries	1,565,592,599.78			1,438,172
6.2 Social contributions and expenses for pension schemes and other benefits of which for pension schemes: €64,343,023.25 (2022: €67,948 (1,000))	354,021,032.34			321,202
		1,919,613,632.12		1,759,374
7. Amortization of intangible assets and depreciation of noncurrent assets		378,507,219.39		344,375
8. Other operating expenses		398,741,213.04		382,832
9. Amortization of financial assets and securities classified as current assets		497,041.03		2,166
10. Interest and similar expenses		282,128.74		278
Total expenditure			**3,224,781,136.55**	**2,927,290**
11. Net income for the year			108,957.54	73
12. Transfers from reserves			5,000.00	–
13. Allocations to reserves			–500.00	–1
14. Annual result			113,457.54	72
15. Allocation to non-profit organization capital			–113,457.54	–72
			–	–

Excerpts from the notes to the 2023 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 local court of Munich under the reference code VR 4461.

The annual financial statements for the year ending December 31, 2023, 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 noncurrent 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.

<table>
<tr><td colspan="3">Annual financial statements of the Fraunhofer-Gesellschaft</td><td rowspan="2">Reconciliation to the income and expense statement format used in single-entry bookkeeping</td></tr>
<tr><td rowspan="6">Balance sheet

Management report

Notes to the financial statements</td><td colspan="2">Income statement</td></tr>
<tr><td colspan="2">Reconciliation between income statement and performance statement</td></tr>
<tr><td colspan="3">Performance statement</td></tr>
<tr><td colspan="3">Budgeted operating expenses and capital expenditure at Fraunhofer-Gesellschaft "Total business volume" level</td></tr>
<tr><td colspan="3">Separate financial statements of the institutes/headquarters</td></tr>
<tr><td>Operating budget
– Costs (excluding depreciation and amortization)
– Income</td><td>Capital expenditure
– Expenses
– Income</td></tr>
</table>

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 1.82 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 2023, pursuant to section 253 (2) HGB. Provisions for partial retirement are calculated on the basis of the policies already concluded.

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 the German language is authoritative. The independent auditor's report is based on the balance sheet at December 31, 2023, the income statement for the financial year 2023 and the full notes to the 2023 financial statements and the 2023 management 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, 2023, the income statement for the financial year from January 1 to December 31, 2023, 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, 2023 to December 31, 2023.

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, 2023, and of its operating results for the financial year commencing January 1, 2023, and ending December 31, 2023.

- 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 (IDW). Our responsibilities under those standards are further described below under the heading "Auditors' responsibility for the audit of the annual financial statements and management report." We declare that we are independent auditors as defined by German commercial law and that we exercise our 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 section 317 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 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 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 is 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 18, 2024
Rödl & Partner GmbH
Wirtschaftsprüfungsgesellschaft

Signature: Grässle
Auditor

Signature: Hahn
Auditor

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

Services

Members, constituent bodies, committees

Members

The Fraunhofer-Gesellschaft has 1,199 members, comprising 44 legal entity members, 63 natural person members, 95 former executive board members and institute directors, 989 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

Dr. Markus Söder

Prof. Erwin Sommer

Prof. Klaus-Dieter Vöhringer

Dr. Hans-Ulrich Wiese

Senate

Representatives from science, industry and public life
Hildegard Müller
Chair of the Senate of the Fraunhofer-Gesellschaft, President of the German Association of the Automotive Industry (VDA)

Kerstin Grosse
Deputy Chair of the Senate of the Fraunhofer-Gesellschaft, Managing Director of DEROSSI Invest GmbH

Prof. Oliver Zipse
Deputy Chair of the Senate of the Fraunhofer-Gesellschaft, Chairman of the Board of Management of BMW AG

Dr. Oliver Blume
Member of the Board of Management of Volkswagen AG, Chairman of the Executive Board of Dr. Ing. h.c. F. Porsche AG

Dr. Roland Busch
President and Chief Executive Officer of Siemens AG

Anja-Isabel Dotzenrath
Executive Vice President of Gas and Low Carbon Energy and Member of the Board of Directors of bp p.l.c.

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

Reiner Hoffmann
Chair of the German Council for Sustainable Development (RNE)

Pär Malmhagen
Senior Advisor

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

Dr. Katrin Sternberg
President Medical and Member of the Management Board of CeramTec GmbH

Dr. Karl Tragl
Chairman of the Executive Board and Chief Executive Officer of Wacker Neuson SE

Grazia Vittadini
Rolls-Royce Chief Technology Officer and Member of the Executive Team

Dr. Anna-Katharina Wittenstein
Member of the Supervisory Board of WITTENSTEIN SE

Prof. Ulrich Rüdiger
Rector, RWTH Aachen University

Prof. Vanessa Wood
Vice President of Knowledge Transfer and Corporate Relations at ETH Zürich

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 Alexander Schott
German Federal Ministry of Defence (BMVg)

Rita Schutt
German Federal Ministry of Finance (BMF)

Representatives at federal state level
State Secretary (Ret.) Ayse Asar
Hessian Ministry of Higher Education, Research, Science and the Arts

State Secretary Dr. Henry Marx
Berlin Senate Department for Higher Education and Research, Health and Long-Term Care

State Secretary Gonca Türkeli-Dehnert
Ministry of Culture and Science of the State of North Rhine-Westphalia

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

Stefan Schmidt
Deputy Chair of the STC,
Fraunhofer Institute for Material Flow and Logistics IML

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

Honorary senator
Prof. Ekkehard D. Schulz

Permanent guests
Prof. Patrick Cramer
President of the Max Planck Society for the Advancement of Science

State Counselor Dr. Eva Gümbel
Hamburg Authority for Science, Research, Equality and Districts

State Secretary Dr. Andreas Handschuh
Saxon State Ministry for Science, Culture and Tourism

Prof. Anke Kaysser-Pyzalla
Chair of the Executive Board of the German Aerospace Center (DLR)

Doris Rösler
Chair of the Fraunhofer-Gesellschaft Central Works Council, Fraunhofer Institute for Building Physics IBP

Stefan Rughöft
Deputy Chair of the Fraunhofer-Gesellschaft Central Works Council, Fraunhofer Institute for Open Communication Systems FOKUS

Prof. Wolfgang Wick
Chair of the German Science and Humanities Council (Wissenschaftsrat, WR)

State Secretary Thomas Wünsch
Ministry of Science, Energy, Climate Protection and Environment of Saxony-Anhalt

Advisory boards

In total, the advisory boards of the institutes consist of 864 members, some of whom hold seats on the advisory boards of more than one institute.

Scientific and Technical Council (STC)

The STC has 220 members, 107 of whom are delegated institute directors or senior managers, while 113 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 nine Fraunhofer groups, named below:

Prof. Karsten Buse
Fraunhofer Group for Light & Surfaces

Prof. Welf-Guntram Drossel
Fraunhofer Group for Production

Prof. Jakob Edler
Fraunhofer Group for Innovation Research

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

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

Executive board

Prof. Holger Hanselka
(President)

Elisabeth Ewen

Dr. Sandra Krey

Prof. Axel Müller-Groeling

Listed information valid as of December 31, 2023

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.

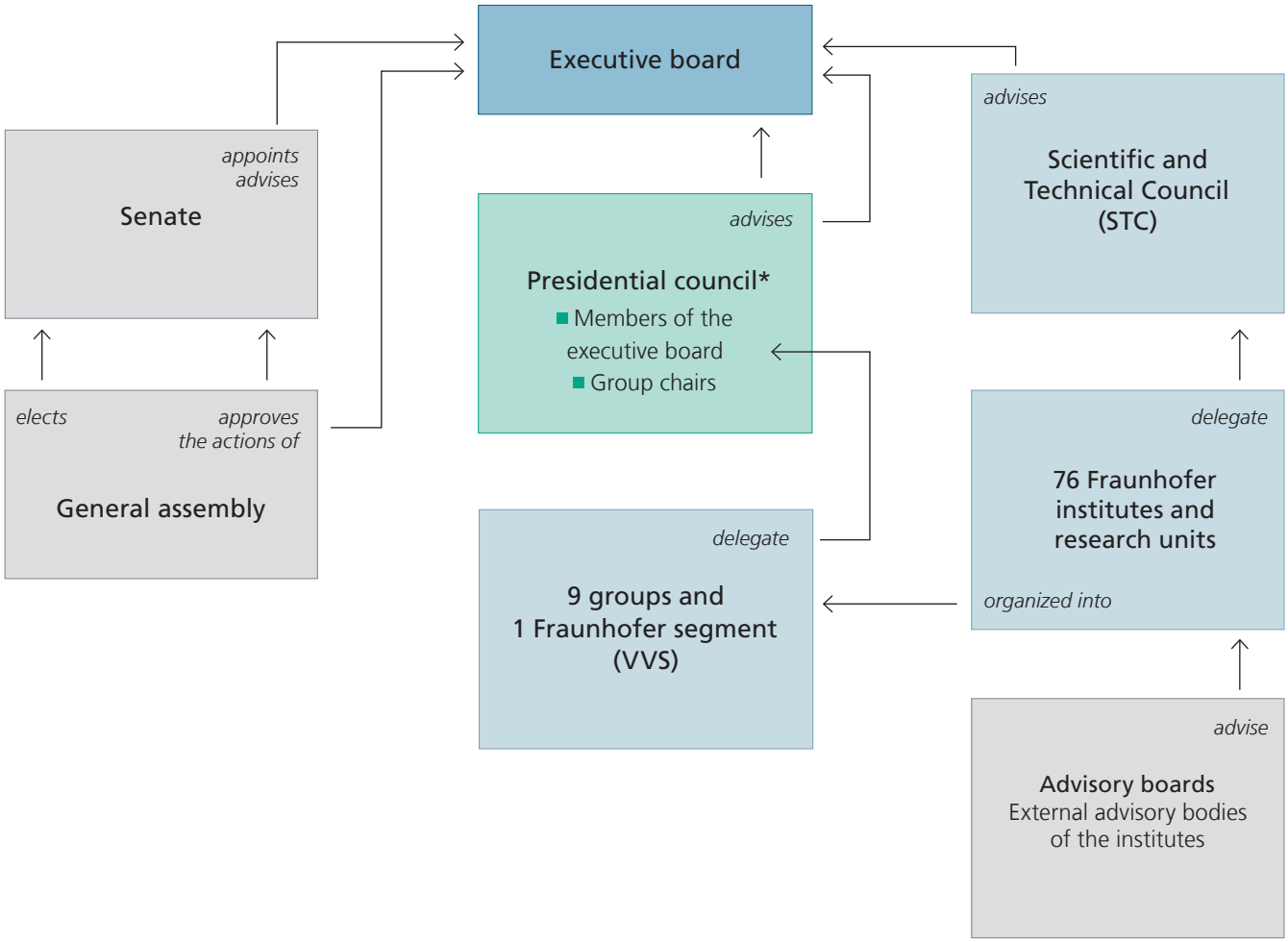
The **senate** comprises a total of 26 voting members from the worlds of industry, science and public life, representatives of the federal and state governments, and members of the Scientific and Technical Council (STC). The senate's duties include appointing members of the executive board, defining the 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 twelve 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.

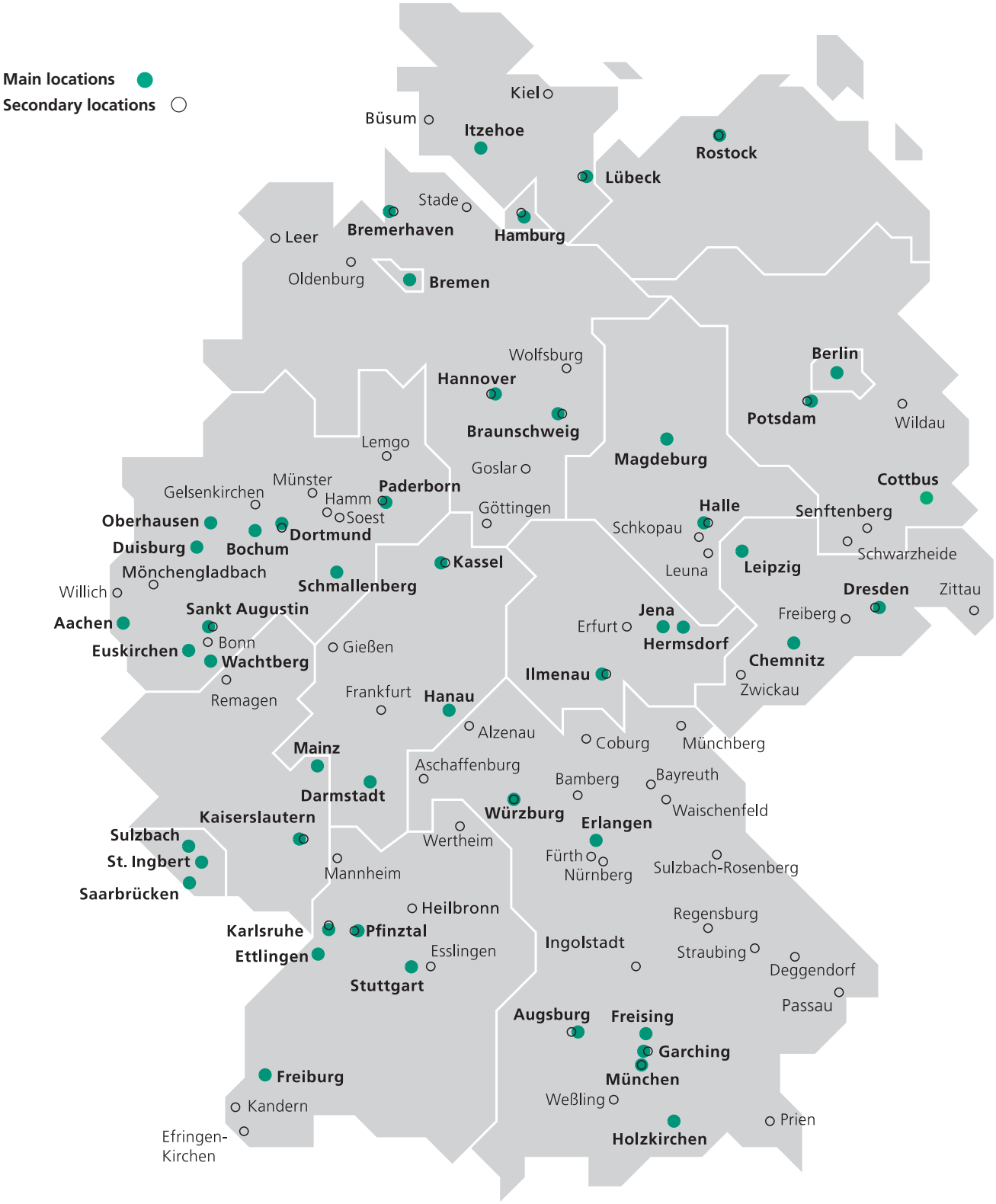
Structure as per the statutes and legal entity



- The Fraunhofer-Gesellschaft is organized as one legal entity, which means all institutes are legally dependent.
- Legal form: association registered under German law (e.V.)
- Tax status: non-profit status

* Advisory committee, not an extended executive board

Fraunhofer Germany



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INNOVATION