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ScienceDirect

Procedia Computer Science 146 (2019) 39–52

Procedia Computer Science

www.elsevier.com/locate/procedia

14th International Conference on Current Research Information Systems, CRIS2018

Fostering Open Science at Fraunhofer

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Abstract

Open science as a paradigm shift in science concerns university or non-university research organizations from the field of not only basic research but also applied research, i.e., research and technology organizations. However, these have a completely different starting point than the other research organizations for the implementation of open science. This is due to their unique position in the innovation system and their close connection with business. In other words, they must meet the demands of both the scientific and economic systems as well as fulfill their overriding mission of conducting research for society. In the interplay between science and business, Fraunhofer has developed a balanced system of control mechanisms and research management topics as well as an infrastructure specifically adapted to the needs of the organization, which is now subject to considerable challenges and changing tendencies due to digitization. These changes affect control processes and related organizational issues as well as the infrastructure around the core business of Fraunhofer – the generation of research output – and the associated infrastructure. This paper discusses how the Fraunhofer-Gesellschaft deals with these requirements with a special focus on dissemination management. The current activities in the field of the Fraunhofer infrastructure and the introduction of a Current Research Information System (CRIS) as an indicator system to measure scientific excellence will be discussed, along with the activities for the implementation of open science.

Acknowledgement:
The authors would like to thank their colleagues Martin Maga, Andrea Wuchner and Anna Seeger (all Fraunhofer IRB), for their help with information detail, data visualization and literature research.

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Peer-review under responsibility of the scientific committee of the 14th International Conference on Current Research Information Systems, CRIS2018.

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10.1016/j.procs.2019.01.078

Keywords: Research Infrastructure, Open Science, Open Science Infrastruktur, applied Science, Research and Technology Organizations (RTO), Open Innovation, Current Research Information System (CRIS), DSpace-CRIS, Exploitation, Intellectual Property (IP), Research Data Management, Data Curation, Open Data, Open Access, Innovation System, Technology Readiness Level (TRL), Open Access Rate, Publication Output.

1. Introduction

Digitization and globalization are megatrends that not only affect the economy but also lead to far-reaching changes in the field of science. Open science describes a paradigm shift from closed to open science. Scientists work in worldwide communities and collaborate in interdisciplinary teams using innovations in the information and communication technology sector to share results and ideas that lead to a fast, dynamic, and effective knowledge transfer and reuse. These developments generally present science organizations, but especially research and technology organizations (RTOs), with major challenges as their unique role in the innovation system requires them to meet the needs of various stakeholders in science, business, politics, and society.

This paper introduces the activities of the Fraunhofer-Gesellschaft in the field of open science and dissemination management. The aim of opening up science and thus democratizing scientific results has now progressed far through political promotion, initiation of a cultural change through the trend of opening up and sharing, development of corresponding infrastructure, and the current transformation of the publishing system.

However, for RTOs such as the Fraunhofer-Gesellschaft, which conduct applied research, this opening cannot easily be achieved, since they have a special role in the innovation system in nations and economic areas and work closely with the industry. As a result, they often deal with sensitive research output that is subject to secrecy and, thus, has limited exploitation rights (intellectual property). Nevertheless, open science has great potential for innovation in general, and especially for RTOs. They must develop an approach tailored to their needs for the implementation of open science and, thereby, have the chance to exploit new opportunities of opening up, both for their partners and themselves.

The first section of this paper introduces the Fraunhofer-Gesellschaft, followed by an explanation of the specific structure and framework conditions of applied research with a focus on the scientific and economic requirements of RTOs. These explanations provide a framework for the activities presented in the context of science management (publication infrastructure and indicator system) and open science.

It then outlines the Fraunhofer research infrastructure as an instrument for managing the generated research output and particularly discusses the introduction of CRIS as an additional internal indicator system for measuring "scientificity." Since 2003, open science has been systematically and carefully established in its various aspects. In addition to the creation of organizational framework conditions and open science infrastructure, Fraunhofer pursues an approach of socio-economic support research for the phenomenon of open science. These new research activities are also exemplified by selected projects. In conclusion, an outlook on expected developments in this field is presented.

2. Fraunhofer Facts & Figures

Joseph Ritter von Fraunhofer (1787–1826) was a German physicist and an optical lens manufacturer. In 1814, he discovered and studied the dark absorption lines in the spectrum of the sun, now known as "Fraunhofer lines." The unprecedented achievement of combining precise scientific work and its practical application, as well as the development of new innovative products, made him the namesake in 1949 of what is today's largest research organization for applied research in Europe. As of June 2018, the Fraunhofer-Gesellschaft maintains 72 institutes and research units. Affiliated international research centers and representative offices facilitate contact with the regions of greatest importance to the present and future scientific progress and economic development. Today, Fraunhofer keeps up the mission to undertake applied research that drives economic development and provides wider benefits for society. Fraunhofer's services are solicited by customers and contractual partners in industry, service sector, and public administration.

In 2017, the research volume amounted to 2.3 billion euros, of which almost 2 billion euros were recorded in contract research. The funding mechanism, the so-called "Fraunhofer Model," is unique in the German research landscape: the company receives funds for around 30% of its expenditure from the federal government (90%) and

the federal states (10%) as institutional funding to conduct preliminary research. The remaining 70% of the expenditure must be covered by its own income, which includes both contracts from industry and publicly financed research projects (federal, state, EU). Since 1973, the amount of basic financing has largely been determined by the level of economic income. This principle applies to society as a whole and to individual institutions. Although the institutes are not legally independent entities, they do have a high degree of independence in choosing their scientific focus, in allocating resources, in acquiring projects, and in managing projects.

The research topics pursued by Fraunhofer reflect the Fraunhofer mission statement's vision of consistently implementing systemically relevant initiatives for Germany. To this end, Fraunhofer is intensifying the cross-institute development of system solutions for seven strategically key topics: battery technology, biological transformation, cognitive systems/data sovereignty, public safety, programmable materials, quantum technology, and translational medicine.

The majority of over 25,000 staff members comprises of qualified scientists and engineers. Academic processes and scientific methods are at the heart of the research business. However, every scientist at Fraunhofer has to simultaneously act economically and is required to focus on customers and markets.

3. Fraunhofer's Academic Side

All research structures at Fraunhofer are geared toward establishing intensive Germany-wide networking with university research. Fraunhofer uses the system of university "affiliated institutes" ("An-Institute"), which is widespread in Germany, through individually regulated cooperation agreements with universities. Affiliated institutes are forms of public–private partnerships (PPP). Fraunhofer currently has cooperation agreements with 64 universities; the number of universities of applied sciences is 48. In 2016, 80 out of 88 of Fraunhofer Institutes' directors (91 %) had a university affiliation [1, p. 94]. The heads of the "An-Institutes" also hold chairs at universities. As a result, research results from Fraunhofer and University "An-Institutes" are directly transferred into lecture content.

Intensive research is also reflected in the number of doctorates: the number of doctoral candidates with a Fraunhofer employment contract at the end of 2016 was 2,053, and a total of 2,858 doctorates were supervised at Fraunhofer [1, p. 59]. The linking of the doctoral topic with specific tasks set by customers and cooperation partners is a unique aspect of the promotion of doctoral students. In this way, doctoral candidates also acquire the ability to approach scientific questions from the perspective of application orientation.

Fraunhofer has an intensive publishing activity. The diverse dissemination formats of the scientific results have been listed and distributed in a central, publicly available, institutional database, the »Fraunhofer-Publica«, since about 1980. Books, journal articles, conference papers and proceedings, posters, presentations, as well as "grey literature" such as technical reports, white papers, or studies are included. There are also registered patents. Fraunhofer-Publica contains 209.528 bibliographic references as of June 1, 2018. Approximately 10,000 more references get added each year. All publications are very precisely classified according to whether they are listed or referenced in the citation databases Web of Science and Scopus, and they can be categorized as "scientific" both internally and externally (see Fig. 1).

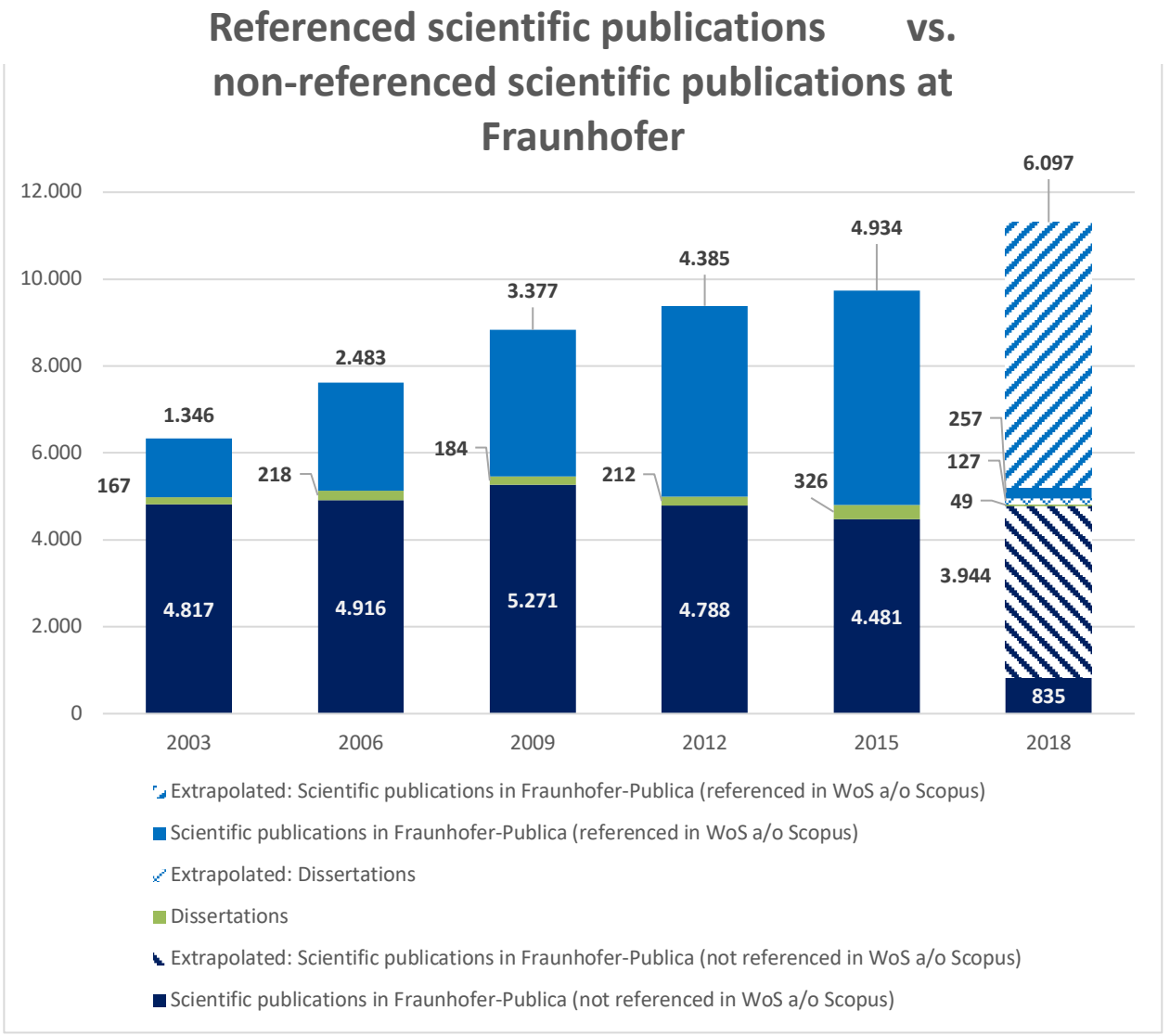

Fig. 1. Publication output: referenced vs. non-referenced publications

The proportion of publications considered to be scientific (referenced publications in Web of Science and/or Scopus) is gradually increasing. However, as can be seen from the publication activity, the standards of a purely academic scientific organization do not apply here. At Fraunhofer, there must also be a constant proportion of publications for target groups other than the scientific community, as Fraunhofer disseminates them on a missionary basis: publications for the interested public (target group: interested laymen and politicians) as well as publications for the professional community (target group: readers in industry and economy).

In addition to its academically oriented structures and typical academic output (e.g. publications in referenced journals and procedia), Fraunhofer has a large number of structures, research business processes, and information processes that differ from academic research and are specifically geared toward industrial applications.

One example is the virtual research facility “Research Fab Microelectronics Germany” [2] that was founded in 2017 and involves 11 Fraunhofer Institutes of the group for Microelectronics and two institutes of the Leibniz Association. Another example that evolves beyond classic academic structures is the formation of new so-called High Performance Centers [3]: In, currently, 16 performance centers spread across Germany, university and non-university research is organized in close cooperation with industry with the aim to create binding, integrated roadmaps for the partners involved in the areas of research and teaching, training and further education, career paths and promotion of young talent, infrastructure, innovation, and knowledge transfer.

4. Fraunhofer’s RTO Side

Applied research is the intermediary between basic academic research and business enterprises. While basic researchers strive for pure scientific progress and the associated gain in knowledge, companies are interested in using technological developments to strengthen their market share or improve their competitive position. RTOs thus incorporate the results of basic research and further develop them for use in companies. This is frequently done in cooperation with interested companies. This bridge between the two parties is necessary as the results of basic

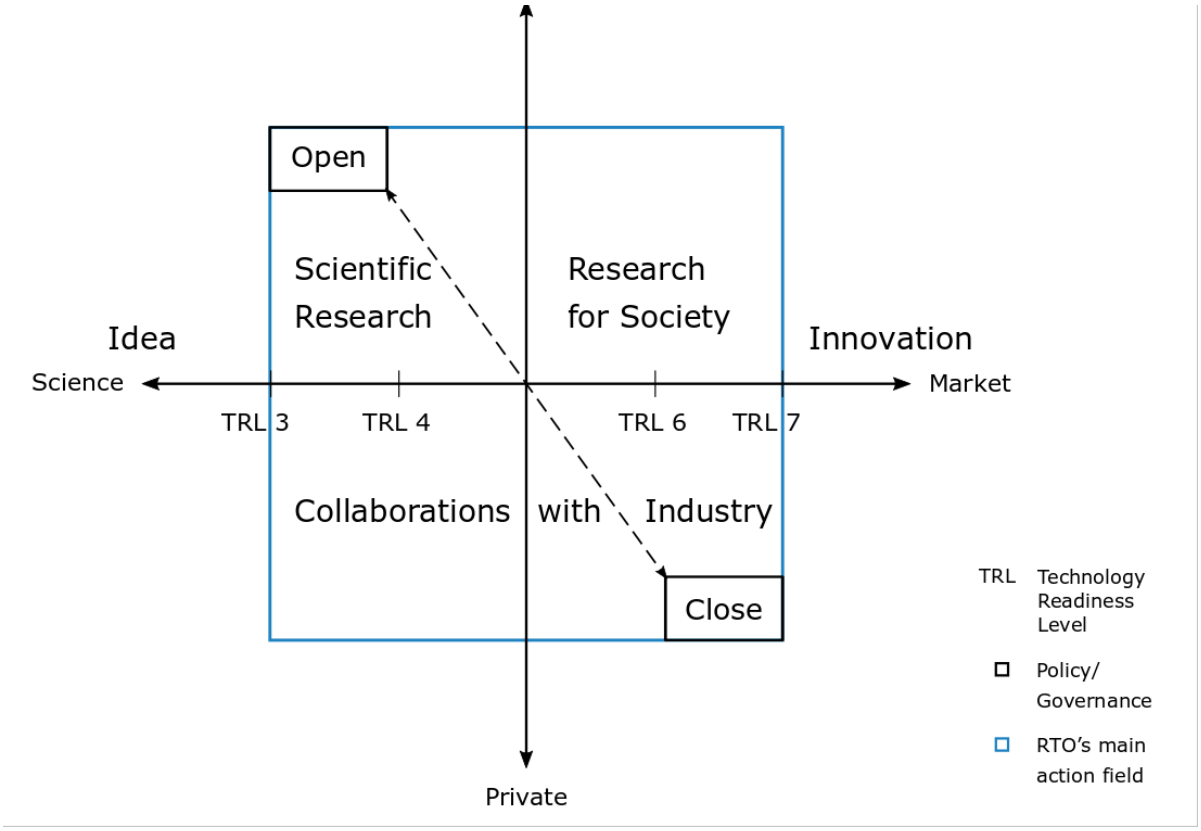

Fig. 2. RTOs and the tension field of open and protected research output

research are not yet technologically mature enough to be directly adopted by companies and be further developed to suit their needs. (Fig. 2)

This is clearly demonstrated by the 9-tiered scale of the so-called Technology Readiness Level (TRL) [4]: the TRL of basic research results is at Levels 1 and 2, applied research is usually at Levels 3 and 4, and can even go up to Level 7, companies usually achieve Levels 7–9, so RTOs serve as a translation mechanism for basic research toward the application of this knowledge. (Fig. 2)

In practice, applied research thus implies that RTOs and their industrial partners can generate IP by conducting research and generating knowledge and technological solutions, which can then be exploited by both partners. The framework conditions for this are defined by coordinated IP regulations in the run-up to the projects [4,5].

With regard to the topics of opening up and exploitation of research results owing to cooperation with companies, it can be assumed that the greater the maturity of technological knowledge, the greater the exploitation interests and, at the same time, the greater the need for IP protection (through patents or utility models) to increase the opportunities for exploitation, e.g., through technology sales, licensing, or spin-offs. It can therefore still be assumed that the probability of opening up this knowledge, in connection with open science, tends to decrease with increasing technological maturity. (Fig. 2) However, it should be borne in mind that, depending on the dynamics of the market in which the technology is positioned, it is also difficult to achieve patent exclusivity, as too many players compete too fiercely for patents on technologies and the issuance of patents is a lengthy and cost-intensive process [6]. There are also initial studies showing that IP protection through patents is not always the best way to exploit technology, e.g., in relation to the possible decrease on companies' innovation performance [7,8]. Also, a partial opening can have advantages, as shown in the open source environment since years. It thus emerges that the most appropriate approach to exploit the generated knowledge in the area of conflict between IP protection and the opening must ideally be decided on a case-by-case basis. This demonstrates that the opening of project results for applied science organizations depends strongly on the respective form, topic, and interests of the partner [6,9–12].

The current challenge here is to deal with various exploitation scenarios of research results. These can range from the classic patent to hybrid forms to complete openness. In the context of exploitation, research data are clearly in the foreground. The Digital Single Market promoted by the European Commission is the vision of an economically thriving Europe where all stakeholders can access and value open data to generate economic, scientific, and social progress. Companies can also benefit from this and integrate freely accessible data, publications, and software into open innovation processes and even integrate them into new business models [13]. For this purpose, it is necessary to develop scenarios and clarify general conditions for RTOs to be involved in opening up and re-using research results. Newer approaches are currently also dealing with exploitation approaches through (partial) opening or through the use of external open data, e.g., in new data-based business models [14–19].

In addition to dealing with stakeholders from science and industry, it is also necessary to find solutions to meet the needs of knowledge transfer in society. There are more and more approaches to social participation, within the research process itself, e.g., citizen science projects (e.g. scistarter.com or zooniverse.org [20,21]), as well as by way of making research results accessible to any interested citizen who wishes to obtain information about the results or technologies that are produced to solve prevailing questions and create added value (e.g. OpenAIRE.eu or innoradar.eu [22,23]).

5. Introduction of CRIS

The quality of research is just as important for successful innovations as the ability to transfer research results into practical application. Fraunhofer has long-established processes and performance measurement systems that control the mission- and promotion-related systematics of the "Fraunhofer Model." These focus on the economic position of the Fraunhofer Institutes, Groups and Alliances. The extent of scientific quality has never been supported by system of indicators and measurement and has never been the basis of the funding model.

For some years now, however, topics of corporate responsibility have been addressed more consciously at Fraunhofer and institutionalized with strategic internal programs and measures. The areas of corporate responsibility include corporate management, employee-oriented personnel policy, economical use of resources, compliance with social and environmental standards, and increasingly ethical scientific responsibility. Ensuring scientific integrity is an absolute necessity for Fraunhofer because the application of high diligence in scientific methods and in data documentation is ultimately the basis for the mutual confidence of business customers, cooperation partners, and the

public. Among other measures to ensure scientific integrity, such as the appointment and institutionalization of ombudsmen at each institute, it was decided to introduce a binding internal system of indicators for scientific excellence.

The "science indicators" are intended at facilitating comparability across all 72 Fraunhofer Institutes and the numerous researched scientific disciplines and dissemination formats. The strategic questions faced by an internal high-level board were the following: with regard to safeguarding its "scientific character," which indicators does Fraunhofer consider relevant, comparable, and measurable in a standardized way in the long term? To this end, a set of scientific indicators was defined under three categories:

- Scientific output category: number of publications of an institute (Scopus reference base), international co-publications, excellence rates of publications, citations, number of patents of an institute.
- Scientific qualification category: number of doctorates (supervised by Fraunhofer Affiliation); number of theses.
- Acknowledgment and academic networking category: high-level awards, spokesmanships, projects of excellence.

The decision for an indicator system was not based on a tool-driven consideration in which, for example, the appropriate measurement indicators were selected from a functionality catalog of commercially available systems. Instead, before the tool decision was made, an evaluation stage was agreed upon, which served solely to check the ability to ascertain and evaluate the logic of the adopted measurement system and, of course, the process acceptance as well. To evaluate the data, a "low-tech approach" with Excel tables was deliberately chosen and, where possible, centralized data were used and all institutes were asked to supply locally held and collected data via an encrypted Excel list. The collected data were then merged into an overall view in Excel after several validation steps by script coding, which then ended in a reporting process for the executive level and the institute management. For two years, feasibility, evaluation, validation, standardization, reporting and communication as well as possible central data storage and delivery were tested.

This was followed by the decision to consolidate and commission the publication infrastructure's central institution to implement further data collection with a web-based information system starting in 2018. Only then the search for a suitable system began. Since the entry logic was not intended to be interrupted, there was only a very short replacement period of about two years for the introduction of the system, while maintaining a transition operation with entry using Excel tables, in which one year was planned with a parallel Excel/CRIS operation.

Open source was very popular right from the start, at the time of selecting the software. The most important criterion was the time saved by avoiding long tender deadlines for commercial products, but the monetary aspects of license-free software were also clearly seen. Another strategic criterion was to minimize vendor obligations and the associated system dependencies (release cycles, external determination for software adaptation, and customization). A decision on DSpace/DSpace-CRIS was made because, among other things, the requirements-based implementation with DSpace-CRIS seems possible without a large adaptation of the software codes, and because of the extensive configuration possibilities of the system, all acquisition and processing logics of the different collection objects and indicator types developed in the evaluation phase could be realized. Since a new repository for the research data management system based on DSpace was planned in a parallel project at the same time, it seemed logical that, if feasible, the use of the same open source software family brought many synergies. Details about the software selection are reported in a blog post of DINI AG FIS [24].

The most important findings from the CRIS project so far are the following:

1. The first stage goal was to standardize the multidimensional collection methods within the organization and to implement them as part of the research infrastructure and business process. An important accompanying effect within the framework of corporate responsibility should also be to assess certain structures, e.g., the status quo of the publication processes and, if possible, to initiate measures for improvement. These quality management effects occurred very quickly and are being systematically processed with the help of a central publication

support team. An indicator system thus seems to have a positive influence on the maturity levels of dissemination processes.

2. Infrastructure design and data management are crucial tasks in building a successful CRIS. But there is no such thing as virgin infrastructure. So, considering the data collection in the CRIS, quite a few compromises needed to be made. Institutes that wished for a fully supported and automated data exchange and import from their local systems found that quite a few data needed to be entered manually into the new web-based system because only then could a controlled vocabulary and quality-controlled input fields be guaranteed. An indicator system can never be built as a standalone system in a grown heterogeneous research organization. There are numerous invasive effects on existing ERP business processes, some of which are self-contained and secured. Especially tightened regulations for data protection and information security require a lot of additional management. Not everything can be solved in a timely and ideal manner.
3. CRIS as a software type is most closely related to the repositories, which is why it also needs to be integrated into the infrastructure of the Fraunhofer repository infrastructure in a timely manner. CRIS meets the Fraunhofer-Publica as an old established database, which is still based on proprietary software and has many connections, e.g., to the library system, to the discovery system, and to external resolvers. For instance, a redesign project has now been initiated for the entire publication infrastructure.
4. Is the CRIS going to lay stress on the social cohesion of the organization? Are the messages of collaboration versus competition always being communicated clearly enough across all levels of contributors in the research process, keeping the balance of research management demands for the purpose of corporate responsibility to not constrict freedom of science? These effects cannot be seen yet, but they should be anticipated and counteracted. Clearly, there is the danger of forcing an unsound divide within the research organization into “scholars” and “performance controllers.” Therefore, one of the key challenges seems to be a wise and goal-oriented communication aimed at winning researchers and management stakeholders over.
5. The principle of introducing CRIS at Fraunhofer with regard to the catalog of requirements and the feasibility study could be called “Structure follows Strategy.” In this respect, the result, which obtains an open source solution with no prior software or provider preference, can naturally be considered positive, aligning nicely with the Fraunhofer Open Science roadmap. However, unlike the publicly accessible repositories, the CRIS will initially only be used internally. In introducing the reporting system, the objective was not create a new research marketing system or share the scientific indicators directly with the outside world. But since the CRIS data forms nearly 75% of the collated, non–confidential, and even published information anyway, the next successful evolutionary step for it would be to enable an open layer and use the CRIS to effectively showcase research results to the world, thus enabling a state of the art research profiling for its research contributors (e.g., by individual author pages, project pages, and institute pages). This could prove a clear opportunity for Fraunhofer to better disseminate research into society.

This brings us to the consideration of the Open Science Evolution at Fraunhofer.

6. The Fraunhofer Open Science Journey

The paradigm shift from closed to open science as described in the introduction is not only being promoted by science but also being increasingly supported by politics in recent years, since Horizon2020 open science has become a key principle in the European Research Area that targets maximum access to scientific knowledge for the economy, society, and research. This aims at a higher level of democratization of knowledge and at improving innovation performance in Europe. Hence, open science is the fundament of the “Digital Single Market,” which is based on free access to research data and publications. Even for the forthcoming Research Framework FP9, “openness” is one of the main principles alongside “impact” and excellence.”

This new approach of opening up the scientific process (open methodology, open peer review, open infrastructure, open notebook, open educational resources, citizen science) and scientific results (open access, open data, open source) can lead to a lot of advantages in the systemic view of the four perspectives of the Quadruplehelix: academia, industry, society, and politics. These advantages are efficiency, quality and integrity, economic benefits, and knowledge transfer [25]. In the course of implementing open science, the Fraunhofer-Gesellschaft is currently focusing on open access and open data and initially on open software, with current activities focusing on enabling free access to publications and data.

The Fraunhofer-Gesellschaft tries to approach the open science topic from different perspectives.

6.1. Open Access

The dynamic development of the scientific system can no longer be imagined without the open science aspect of open access. As early as 2003, Fraunhofer, as one of the first signatories of the Berlin Declaration, stated that open access should have major advantages for applied research. Since 2003, the proportion of full texts available in open access has been increasing continuously. Currently, 18.276 documents are freely available in the open access repository "Fraunhofer-ePrints." Of these, 3.463 are flagged as "scientific" or referenced in WoS and/or Scopus.

With the open access strategy [26] adopted in October 2015, Fraunhofer has set out clear goals for further increasing the open access share of its scientific publications: by 2020, 50% of Fraunhofer's annual publications should be freely accessible. Various measures are being taken to achieve the ambitious target share of open access publications. Since 2017, for example, a central APC fund has been promoting original open access publications ("golden path" of open access). Fraunhofer is also actively involved in the "Open Access 2020" initiative [27], which aims to convert scientific journals to gold open access on a global scale. The internal "Open Access transition" workgroup is working on the data bases and structures required for this purpose at Fraunhofer. Here, it was achieved that Fraunhofer recently joined the "OpenAPC" initiative [28,29]. In line with the German federal Open Access Strategy [30], these measures aim to establish open access as a standard for scientific publishing in the medium term. While in 2012 the open access share was just under 14% (7.8% on the "green path" and 6.1% on the "golden path"), an increase to 20.3% can be observed for 2015. (Fig. 3)

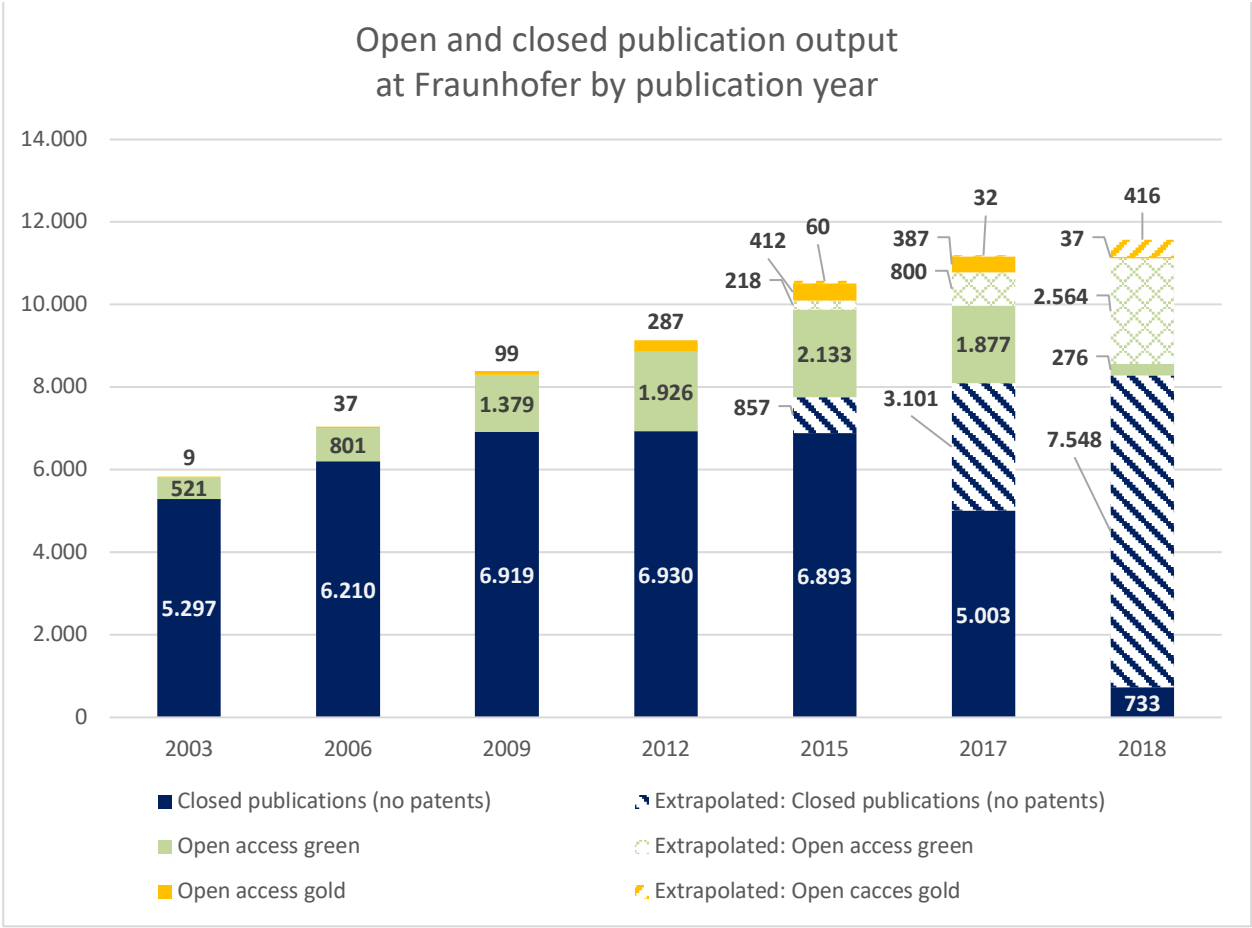

Fig. 3: Development of Open Access numbers in all forms at Fraunhofer.

6.2. Open Data

To take account of developments in the field of open data, the project FORDATIS - Research Data Infrastructure at Fraunhofer is being carried out at the publication infrastructure provider, Fraunhofer IRB. First, the status quo of research data management among scientists, information managers, and IT managers as well as that of handling research data and existing needs was assessed through a survey. This clearly showed that there is a need for training, consulting, and infrastructure among all three groups surveyed. A Fraunhofer-wide research data repository for published and to-be-published research data based on the DSpace (open source) software is currently under construction. This will be compliant with the requirements of the European Commission, particularly the FAIR principles, and is intended to reinforce the international visibility of research results. The repository has already been specified and a metadata schema has been created. FORDATIS has links to other current infrastructure projects: FORDATIS will be integrated into the redesigned publication infrastructure of the Fraunhofer-Gesellschaft so that an exchange of metadata and a comprehensive search will be possible. The project HEFE, funded by German Federal Ministry of Education and Research (BMBF), deals with the development of data governance, is working on future possibilities for the exploitation and business models of research data. Furthermore, the “FAIRness-Grade” of FORDATIS will be evaluated as part of a Fraunhofer-wide digitization project. On a larger scale, FORDATIS will interact with the planned National Research Data Infrastructure (NFDI) [31] and be connectable to the European

Open Science Cloud. A policy for the precise regulation of the provision of research data for the Fraunhofer Institutes is in preparation.

In contrast to academic research environments, the mere establishment of a publication infrastructure for research data is far from sufficient at Fraunhofer. As mentioned before, RTOs that often collaborate with the industry face challenges in terms of being members of both the scientific system and the economic context. So, the protection of IPR (Intellectual Property Rights) is vital for them to be able to create value together with their project partners who want to secure their knowledge to be able to gain competitive advantages and transfer the knowledge into innovations. So, open science is feasible for RTOs under the premise of making scientific results as open as possible but as closed as necessary. Scenarios for the use of open data and software are therefore particularly in demand. New business models need to be developed in order to achieve this goal together with stakeholders from industry, cities, and municipalities, if necessary. In addition to publication infrastructure, further technical infrastructure is necessary to enable Fraunhofer scientists within their projects to decide, together with cooperation partners, the extent to which the research results should be exploited in the area of conflict between IP protection and openness. One possible way to manage IP-relevant data is now offered by potential solutions in the area of blockchain/IPFS technologies. Systems for the certification of data packages and their integrity are particularly promising and must be tested for an open ready-disclosure process.

6.3. Research on Open Science

Scientific consideration of the impact of open science on the scientific system is also important. Fraunhofer is currently investigating various research topics on the realization of open science, taking into account the special position of applied research organizations. Current questions concern themes such as the development of data governance concepts and process models to ensure a targeted and sustainable handling of research data at the institutes. Two nationally funded research projects and one EU project are presented below as examples.

1. The BMBF-funded project HEFE (Heterogeneous research data in the urban context): Governance for analysis, planning, and real-time data - Project HEFE. The aim of this project, on which the Fraunhofer IRB and the Fraunhofer IAO are working together, is to develop a concept for the control processes of research data within a field of research with a focus on urban data. In addition to dealing with the processes and requirements of data generation, data management, and reuse processing, the project also deals with possible utilization scenarios with regard to data-based business models.
2. The BMBF-funded project “Citizen Sensor,” in which a Fraunhofer Institute (Fraunhofer EMFT) develops a measurement sensor together with the FabLab Munich (maker scene, civil scientists), has another priority. An accompanying goal of the project is also an action guideline for the cooperation between scientific organizations and civic scientists, which helps to support this special form of cooperation in terms of the way of interaction up to the regulation of the exploitation of the collectively generated results [32].
3. The EU-funded JERRI project (Joining Efforts for Responsible Research and Innovation) aims to contribute to the institutionalization of Responsible Research and Innovation (RRI) in the European Research Area. For this purpose, JERRI coordinates an RRI change process within the two largest RTOs in Europe: the Fraunhofer-Gesellschaft and the Dutch Organization for Applied Scientific Research, TNO. This process is conceived as an intensive, mutual learning process between both organizations and other RTOs and stakeholders. The aim is to develop objectives and action plans with regard to the dimensions of RRI. These include social commitment, gender, scientific education, open access, ethics, and governance. In the open access dimension, work is currently being carried out on setting up and testing FORDATI's research data infrastructure and developing an associated communication concept for the organizational penetration of the topic of open access into research data. Another question relates to exploitation possibilities and business models for RTOs based on open data [33]. Furthermore, other Fraunhofer Institutes are working on several projects in the fields of open source, open education, and open infrastructure.

4. The holistic scientific approach to this topic is also part of the portfolio of Fraunhofer Group for Innovation Research, which was founded in 2017. It has set for itself the task of studying the innovation system and the associated current and future developments at the micro- and macro-economic levels, thereby providing orientation as well as positioning and shaping the future for business, society, and politics [34].

7. Conclusions

The open science trend continues and, in addition to the scientific community, the trend is being strongly promoted politically, as will become evident in the forthcoming FP9 research framework program [35]. Fraunhofer is pursuing this path as well and, although it has a special structure and position in the innovation system, it is trying to implement open science in the best possible way and to leverage the associated potential while considering the interests of all stakeholders. Also, the necessity of fostering open science is clearly driven by Fraunhofer's academic side. Then again, Fraunhofer's budget depends largely on its success in maximizing revenue from doing scientific research for industry partners and the public at large. In this spirit, the institutes and their employees will continue to act entrepreneurially and ideally combine open science approaches in research with the entrepreneurial mindset. Consequently, open science at Fraunhofer will be successful if it succeeds in integrating the concept into the Fraunhofer business model. Thus, open science will not fundamentally change the Fraunhofer Model, but rather enrich it. This requires the development of the Fraunhofer action framework "as open as possible, as closed as necessary."

For the general implementation of open science in science organizations, a whole series of heterogeneous questions still have to be investigated and answered in order to exploit the full scientific, economic, and social potential of open science. In addition to the technical and organizational implementation (governance processes, interfaces, infrastructure networking, standardization, long-term archiving), this also concerns the legal framework (e.g., copyright to data, licensing models) and the political framework (promotion, establishment of open science support). Furthermore, it concerns the development and establishment of processes and associated role concepts and responsibilities (producer, manager, curator, user, etc. of publications, data, and software) [36].

The European Working Group on Education and Skills has published useful recommendations on the desiderata for successful open science application: development and implementation of policies and guidelines for open science, increased communication to create awareness of open science, competence development for open science, support in the implementation of open science, and development of career paths in the area of open science [37].

The often-postulated radical change of culture and mindset in the research community is also needed at Fraunhofer. "Traditional, pre-digital, scholarly communication mechanisms and structures for rewards and recognition are deeply embedded within the current academic practice, and new technology has not yet fully been adopted in daily research routines. The Digital Skills Agenda that provides researchers with the skills and competencies that they need to practice open science is clearly not fully implemented" [37, p. 26]. Another need for development in research organizations that should not be underestimated is the need for people involved in building competence in data management, data analysis, data visualization, etc. The complexity of the topic and its influence at almost all levels of governance make it indispensable to overcome disciplinary boundaries and develop new competence profiles.

Both in infrastructure development and in the area of open science strategy development, however, the "Open Science Journey" currently appears quite disjoint in Europe. As an example, the countless different open access policies at state and federal level and the question of how these should be addressed by a research institution represented nationwide should be cited. The numerous national and international initiatives to promote open science could greatly increase their impact in terms of implementation by harmonizing activities. Ultimately, the initiation and support of a cultural change toward sustainable management and the opening of research output is the prerequisite for the implementation of open science. This presupposes the development of new reputation mechanisms and incentive systems to enable and motivate the players to explore the open science paradigm.

For the future, we clearly see the need of a unique new science indicator for openness, research transparency, and open science engagement. This could be the accelerator for open science dissemination at Fraunhofer as well as a valuable incentive for Fraunhofer CRIS.

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