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Fraunhofer future markets: From global challenges to dedicated, technological, collaborative research projects

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One urgent mission for European research is to focus on the grand challenges of our time. We discuss how this mission was incorporated into a Fraunhofer corporate programme that takes on global challenges by stimulating collaborative research projects across knowledge domains. Fraunhofer's mission is to conduct innovation-oriented research for the benefit of private and public enterprises as well as society in general. As a decentralised organisation, Fraunhofer's strategic R&D planning predominantly takes place at the level of its 60 institutes and its six groups of institutes, each with similar technological scope. At the corporate level, Fraunhofer complements these strategic planning activities with a process to identify and strategically develop research themes across its institutes. In this paper, we address the question of global challenges, their definition, why and how Fraunhofer can best direct its overarching research topics towards solutions for some of the global challenges.

Keywords: foresight; future markets; grand challenges; global challenges; megatrends; societal demand.

1. Introduction: The idea

The Lund Declaration (Lund Declaration 2009) formulated a request that European research should focus on the grand challenges of our time, moving beyond current rigid thematic approaches. This enhanced the existing discussion about challenges and needs-oriented approaches versus a science and technology push. Grand challenges are discussed at many levels, for instance, the EU, the regions, nations, cities and organisations. Even the new Framework Programme 'Horizon 2020' will stress programmes that are based on 'social challenges' (European Commission 2011: 5ff) and will dedicate a significant amount of money to these challenges.

The Fraunhofer Society is Europe's largest contract research organisation and is taking this request seriously, by adapting its corporate process for defining and developing research themes across its institutes.

Fraunhofer's strategic R&D planning predominantly takes place at the level of its 60 institutes and its six groups of institutes, each with a similar technological scope. The strategic planning activities are complemented by a process which aims to identify and strategically develop research themes across institutes (Fraunhofer Future Topics). This process is repeated every three years (Klingner and Behlau 2008).

In order to differentiate from the rather technology-driven processes of the past, a new approach was sought. This new strategy process should orient itself more towards demand-driven questions. That means following the principles of corporate social responsibility and developing new ways for Fraunhofer research markets of the future. The idea fits well with the Fraunhofer mission,

which is to conduct innovation-oriented research for the benefit of private and public enterprises, as well as society in general. But the first question to ask was: What are the global challenges and questions of the future?

In this paper, we therefore address the question of global challenges, their definition, why Fraunhofer undertakes such an endeavour and how Fraunhofer can best direct its strategic research towards solutions for some of the global challenges.

2. Framework: Some definitions of global challenges

Global challenges, or 'grand challenges' as they are often called, are discussed at nearly every conference or workshop. But when a definition is called for, it is still unclear what different people are talking about and what we should 'address' as a global challenge (see Lund Declaration 2009; EU 2011 or the different definitions given during the presentations at the Innovation Convention, held 5–6 December 2011 in Brussels). Some institutions and companies have lists of megatrends and regard them as global challenges. Some go even further and try to identify what is lying ahead—without looking into the past.

Global challenges therefore represent different strands of issues (authors' own observation):

- Some selected trends or 'megatrends' that are observed in a global context.
- Global problems which have already been identified.
- Unknown unknowns—some problems that will occur, but which have not yet been identified.

All definitions have in common that the global challenges need answers and solutions and that they will have a huge impact if no solutions are found to solve the 'problems' or find answers for identified trends. All global challenges are valid for a longer term (more than 20 years, some even say more than 50 years).

Some global challenges have multiple dimensions, so that:

> ... the current government systems are incapable of tackling current and future global interconnected challenges. (Boden et al. 2010: 24)

The challenges to developing countries are also becoming global.

Different publications or internal papers can be discussed, in order to give some examples of these different views of global challenges that were starting points for the Fraunhofer considerations.

2.1.1 First example. In parallel with the Lund Declaration (2009), the European Commission published some brochures about the 'challenges'. One is 'The World in 2025' (EU Commission 2009), which argues about trends, tensions and major transitions. Here the (mega-) trends and the global problems are derived from the 'tensions' described in this approach.

Trends mentioned are (EU Commission 2009: 11ff):

- The Asian century is approaching, with nearly two-thirds of the world's population living in Asia (in 2025), with increasing inequalities and Asia as the first producer and exporter of the world.
- Under the headline of poverty and mobility of men and women, it is assumed that international migrations will develop and, without an important inflow of immigrants, the European population would start to decrease from 2012. A third of the world's population is undernourished. On the other hand, obesity is on the increase in developed countries. Although the global health situation is improving, new risks are emerging.
- The last trend is the increasing scarcity of natural resources and the vulnerability of the planet with the new geopolitics of energy, with more than 50% of the major reserves located in very poor countries and three billion people lacking water.

Tensions are not worked out as 'problems', but are described as tensions:

- between the current methods of production, consumption and the future availability of non-renewable resources
- between a general and simultaneous process of increasing economic interdependence and differentiation
- between spatial proximity in the context of accelerated urbanisation and cultural distance (EU Commission 2009: 19ff)

In this context, transitions are assumed to be:

- towards a multi-polar world and world governance
- towards a new universalism (political-cultural transition)
- towards a 'large integrated Europe' and a 'global Europe'
- towards a new 'socio-ecological production model' (here it is assumed that the ecological and demographic challenges will be tapped/harnessed to invent a new development model)
- urban transition and the new 'territorial dynamics'
- demographic change and 'active ageing' (EU Commission 2009: 19ff)

These transitions are also considered to be 'megatrends' in other publications. The term 'megatrends' was originally used by Naisbitt (1984) and was taken up in Germany by popular trend searchers like Horx (2007) who defines them as the:

> ... blockbusters of the forces that change. In a hierarchical trend system, they are active at different levels. They change

> and invade patterns of civilisation, technology, economy, and value systems. Megatrends have a half-life of at least 50 years, are resistant to set-backs and show impacts in all areas of the lives of human beings.

But in these and many other cases (Popcorn 1993, 1999) of megatrend discussions, the definition of the megatrends was not explained and the sources remain unrevealed. Nevertheless, many people 'felt' that they could agree with these trends—without any scientific proof. As the word 'megatrend' became popular, sociologists and researchers from different disciplines tried to find more evidence for megatrends. They made use of different trend lines from historical data and identified long-lasting developments, sometimes in combinations of more than one line, with large impacts that were additionally identified.

Some researchers from different areas made use of these approaches and set 'megatrends' as a framework or a driver for their scenarios (Kolz et al. 2012 forthcoming). They were even part of a Delphi survey (Cuhls et al. 2002; Blind et al. 2001) to highlight topics that should be assessed in science and technology. Megatrends are also used as a part of the evaluation in market studies and analysis (Frost and Sullivan, 2010).

2.1.2 Second example. The State of the Future reports of the UN Millennium Project can be regarded as another source for 'megatrends' and long-lasting challenges for the future. The Millennium Project is designed to provide an ongoing capacity as an intellectually, geographically, and institutionally dispersed think-tank. It is designed to provide an independent, global capacity that is interdisciplinary, interinstitutional, and multicultural for early alert and analysis of long-range issues, opportunities, challenges and strategies. The information generated is made available through a variety of media for consideration in policy-making, advanced training, public education and feedback. (see Glenn et al. 2009; for a brief introduction see Cuhls 2008). These reports served as a basis for the challenges for the Fraunhofer Society (see below).

2.1.3 Third example. The challenges pointed out in the State of the Future reports are based on the UN Millennium Challenges and Goals Project (2005). The goals are transferred into strategic targets. The Millennium Development Goals as a focus for action (see also Cuhls 2008 and citations there) are listed in Table 1.

These targets and global goals can be described as 'large permanent problems'. Some have been known for a long time, but still remain problematic—and are therefore still challenges. Others are rather new developments. All the problems and challenges identified here are those that can somehow be dealt with by the means human beings have at their disposal. They are not dealing with sudden events or 'wild cards' (in the sense of Steinmüller and Steinmüller 2004; Steinmüller 2011) and all of them have been ongoing problems for a long time—so at the same time, they are based on trends or megatrends. The State of the Future reports that are published every year take stock of these permanent challenges and report on the developments: Are there improvements or is there stagnation in addressing the challenges? To the best knowledge of the present authors, the State of the Future report is the most comprehensive and scientifically accepted description and monitoring of the large challenges that have global impacts (global or grand challenges) and was therefore regarded as an appropriate starting point for the Fraunhofer Future Markets process.

2.1.4 Fourth example. The fourth example is from the Fraunhofer Society itself. The Fraunhofer Society (see below) came up with its own list of challenges. These were derived from what was regarded as peoples' 'needs' and are therefore in the background of fields in which Fraunhofer should be active. There was no long-standing process to formulate these types of megatrends or challenges.

The Fraunhofer list (internal paper) of 2006 included: technology megatrends, converging technologies, 'biologilisation', miniaturisation, intelligent environments etc. These developments were directly addressed in the Fraunhofer foresight process at that time (Klingner et al. 2008).

2.1.5 Fifth example. The new version of the German 'hightech strategy'[1] (Bundesministerium für Bildung und Forschung 2010) has defined needs-oriented fields (*Bedarfsfelder* in German) and key technologies as a frame for reference. In their argumentation, they are also referred to as large or 'global challenges' although, of course, they are set in the context of Germany. But it is impossible to think of Germany meanwhile without its global context. the fields of the hightech strategy are:

- climate/energy
- health/nutrition
- mobility
- security
- communication

Interestingly, there seems to be a considerable level of consensus on the upcoming challenges. Whenever a list is published, it resembles an existing one. Some are more summative, others are more detailed. But although many institutions or organisations have their own lists, most of the institutions use the lists as a frame of reference and do not integrate the items into their own work or (strategic)

Table 1. Goals and targets of UN Millennium Challenges

Goal 1	Eradicate extreme hunger and poverty
Target 1	Halve, between 1990 and 2015, proportion of people whose income is less than US$1 a day
Target 2	Halve, between 1990 and 2015, proportion of people who suffer from hunger
Goal 2	Achieve universal primary education
Target 3	Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling
Goal 3	Promote gender equality and empower women
Target 4	Eliminate gender disparity in primary and secondary education, preferably by 2005, and at all levels of education no later than 2015
Goal 4	Reduce child mortality
Target 5	Reduce by two-thirds, between 1990 and 2015, under-five mortality rate
Goal 5	Improve maternal health
Target 6	Reduce by three-quarters, between 1990 and 2015, maternal mortality ratio
Goal 6	Combat HIV/AIDS, malaria and other diseases
Target 7	Have halted by 2015 and begun to reverse spread of HIV/AIDS
Target 8	Have halted by 2015 and begun to reverse incidence of malaria and other major diseases
Goal 7	Ensure environmental sustainability
Target 9	Integrate principles of sustainable development into country policies and programs and reverse loss of environmental resources
Target 10	Halve, by 2015, proportion of people without sustainable access to safe drinking water and basic sanitation
Target 11	Have achieved by 2020 a significant improvement in lives of at least 100 million slum dwellers
Goal 8	Develop a global partnership for development
Target 12	Develop further an open, rule-based predictable non-discriminatory trading and financial system (includes a commitment to good governance, development, and poverty reduction, both nationally and internationally)
Target 13	Address special needs of least developed countries (includes tariff- and quota-free access for least developed countries' exports, enhanced program of debt relief for heavily indebted poor countries (HIPCs) and cancellation of official bilateral debt, and more generous official development assistance for countries committed to poverty reduction)
Target 14	Address special needs of landlocked developing countries and small island developing states (through Program of Action for the Sustainable Development of Small Island Developing States and 22nd General Assembly provisions)
Target 15	Deal comprehensively with debt problems of developing countries through national and international measures in order to make debt sustainable in long term

goals. This was, however, what the Fraunhofer Society attempted to do.

But why did the Fraunhofer Society define 'its' global challenges? How does one of the largest research organisations in Europe re-orient itself towards these challenges? For this, we need first of all to look at the Fraunhofer Society itself.

3. The Fraunhofer approach

3.1 Strategic R&D planning within the Fraunhofer governance model

Future-oriented technology analysis (FTA) approaches have been used within corporate strategic R&D planning at Fraunhofer for several years. When assessing the scope and impact of these activities, it is useful to consider the specifics of the 'Fraunhofer innovation system' and the role of strategic R&D planning at the corporate level within this system.

With a total budget of €1.65 billion in 2010, Fraunhofer is the largest contract research organisation in Europe. Fraunhofer's contract research turnover has three main sources. Roughly one-third is provided through basic funding by the German government. The other two-thirds are acquired by the individual institutes, either through publicly funded projects within consortia or through bilateral contract research with industry. Fraunhofer has a highly decentralised governance model. Individual institutes may set their strategic and scientific focus very autonomously, as long as they manage to balance their budget and stay in line with Fraunhofer's general strategic scope.

Compared to other publicly funded research organisations in Germany, the share of industry revenues is relatively high and a unique feature of Fraunhofer. In order to foster this feature, a self-regulating financial model is used to allocate basic funding among the institutes. A large amount of the above-mentioned basic funding is distributed to the institutes via a competitive key which encourages them to operate within a specific ratio of industrial revenues. When institutes acquire 25–55% of their total budget through contract research with industry, they are rewarded with a higher share of basic funding than institutes operating outside that corridor, i.e. with a share of less than 25% or more than 55% of their revenue from industry.

This financial model strengthens the competitiveness of the individual institutes in the industrial contract research market, but also leads to a certain degree of competition between them. At the same time, cooperation between various knowledge domains within 60 Fraunhofer institutes is needed to address complex interdisciplinary system approaches in R&D. Hence Fraunhofer fosters

and intensifies cooperation between institutes to fully utilise the strength of its broad R&D portfolio with various measures. Institutes of similar scientific and technological scope form a total of six groups representing Fraunhofer knowledge domains (information and communications technologies, life sciences, materials, light and surfaces, microelectronics, and production). Within the groups, institutes plan and strategically align their respective R&D portfolios. Another platform of cooperation is built by the 20 Fraunhofer alliances, in which institutes team up to represent specific fields of expertise to the market (e.g. water systems, cloud computing, lightweight structures etc.). Members of an alliance often come from different institute groups thus exhibiting the transdisciplinary nature of the alliances. Moreover, Fraunhofer headquarters fund internal research programmes for joint R&D projects in order to support cooperation between the institutes.

Another approach to fostering cooperation and strategic areas of excellence is the identification of specific strategic future topics at the corporate level, using FTA methods. One of the approaches is described in Klingner and Behlau (2008). Successful implementation of such processes achieves several goals: the identification of strategic future topics that will produce future contract research markets for Fraunhofer; serving urgent societal needs; supporting cross-domain cooperation in order to become the best in the respective field, and gaining broad acceptance for the distributed Fraunhofer entities.

FTA in this context supports Fraunhofer's strategic R&D planning. Hence, it needs to be action-oriented and results should be quickly implementable to create the maximum impact in the organisation in the shortest possible time.

3.2 Former future-oriented processes at Fraunhofer (technology-driven)

In 2004, Fraunhofer performed its first future-oriented process at a corporate level to identify strategic future topics across the institutes. This approach started with a portfolio generation, on the one hand, and the aim to identify important future fields for the Fraunhofer Society on the other hand. Methodologically, the analysis of different foresight activities in different countries was at the forefront. From these analyses, a core team composed of Fraunhofer and external experts identified and described 50 technology trends and discussed them in a workshop with experts (see Fig. 1). A total of 12 future perspectives were identified for publication and these topics were fostered by funding Fraunhofer-specific internal projects.

This first approach was followed by a second process in 2008 (Klingner and Behlau 2008). In this approach, the analysis of foresight studies was only a small work package followed by an internal survey to generate topics. In a second survey, the themes that emerged were ranked according to a set of criteria. The survey identified 25 focus themes which were described and re-assessed, taking account of the results of the expert interviews, so that ultimately 12 future topics were formulated (Klingner and Behlau 2008).

Although the processes differed slightly in the methodology used, their common conceptual background can be characterised as portfolio-oriented and technology-driven: the starting point of the processes was technologies and technological approaches. Both processes were started to enhance or update the Fraunhofer Society's thematic portfolio.

Papers on foresight studies or specific technological R&D trends were analysed and evaluated as the starting point. Experts with different technological backgrounds met in workshops to discuss and assess the future relevance of certain technologies by extrapolating the current R&D portfolio to the future. This approach is common for a technological-driven organisation like the Fraunhofer Society. It fits with an attitude often associated with technicians, engineers and scientists that can be, in a slightly exaggerated way, formulated as 'Let's drive this interesting and fascinating technology further. Later on, we will find out what it can be used for.'.

At the end of the 2005 and 2008 FTA processes, 12 innovation topics, that became 12 Fraunhofer future topics were defined. Defining the topics served as the background for the institutes to shape and develop the topics further: it provided them with a kind of discussion platform. Equipped with roadmaps and claims for internal and external communication, institute consortia contributing to the future topics could apply for further internal and external funding. However, dedicated internal funding for each topic was not inherent in the process.

3.3 Rationale for a new 2010 future-oriented process (demand-driven)

The rationale of the Fraunhofer approach started with the assumption that there are obviously science- and technology-driven approaches that make use of long-term thinking, but that the opposite (needs-driven) approaches are rare. Some of these needs can be defined by the global/grand challenges. This does not mean that the entire research landscape should be focused on global/grand challenges alone, but that a more active part is needed here. The Lund Declaration (2009) made clear that:

> European research must focus on the grand challenges of our time moving beyond current rigid thematic approaches. This calls for a new deal among European institutions and Member States, in which European and national instruments are well aligned and cooperation builds on transparency and trust.

Therefore, every research organisation and every actor in the innovation system has to position itself or himself in

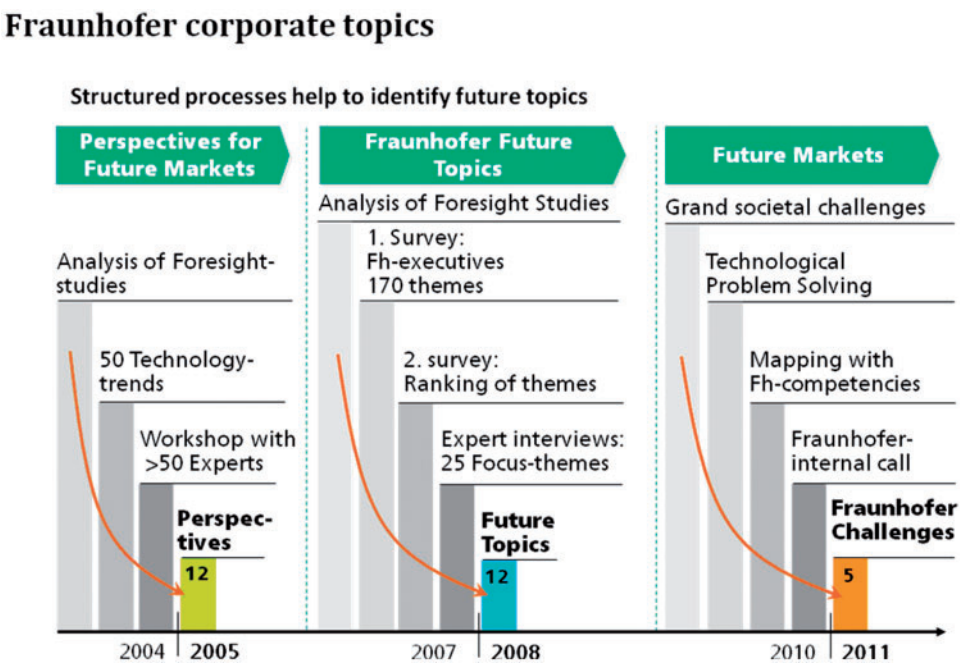

Figure 1. Fraunhofer future processes.

this new arena and consider what the grand challenges means for itself or himself. As Fraunhofer is one of the largest actors in the European system, it is obvious that its headquarters had to act to position the Fraunhofer Society.

For Fraunhofer itself, this question was already posed earlier because within the Fraunhofer Society with its 60 institutes, there is a broad portfolio with a huge variety of scientific disciplines, applications and knowledge in general available. Therefore, with intelligent cooperation, global challenges can be addressed and, for Fraunhofer, an add-on can be identified by directing these cooperations towards something that is supposed to deliver early results.

The idea was to define pragmatic areas in order to foster this cooperation. Global or grand challenges were therefore regarded as a 'means' to direct Fraunhofer's collaborative research into a direction with societal impact. The global challenges that could be addressed by Fraunhofer institutes in general were identified, and projects to actively promote solution-finding were called for. In order to support these projects, budgets were provided only for projects spanning the knowledge domains. This approach left the scientists enough freedom to find their own solutions. On the other hand, the—often technically minded—researchers are forced to think outside their normal boxes. In this case, no complicated or sophisticated solution is sought, but rather projects with potentially high impacts on the societal questions of the future.

The aim of the 2010 process was that, ultimately, each future topic would be promoted and developed by at least one dedicated (and centrally funded) R&D project of significant size. That means 'real' prototypes or results developed in a collaborative manner are expected from the projects. Section 4 explains this process in more detail.

4. Methodology of the 2010 process

4.1 The concept of the 2010 future-oriented Fraunhofer process

The main objective of the Fraunhofer process was to identify and develop research topics across the Fraunhofer knowledge domains represented by the institutes and groups of institutes. A needs-oriented approach and cross-institute problem-solving should open up new contract research markets in a 3–7 year perspective, i.e. an actual market perspective of 5–10 years.

The process had a first top-down part, in which global societal challenges were analysed and adapted to Fraunhofer-specific challenges. The specific challenges served as a framework for the second, bottom-up, part of the process. Within a competitive call, institutes teamed up to develop technological solutions to the challenges in the form of collaborative project proposals. The most convincing projects were funded internally.

4.2 Deriving Fraunhofer-specific challenges from global challenges

The 2009 State of the Future report of the UN Millennium Project was chosen (Glenn et al. 2009) as a starting point for deriving the Fraunhofer challenges (see Fig. 2). The comprehensive, reliable, and widely accepted metastudy

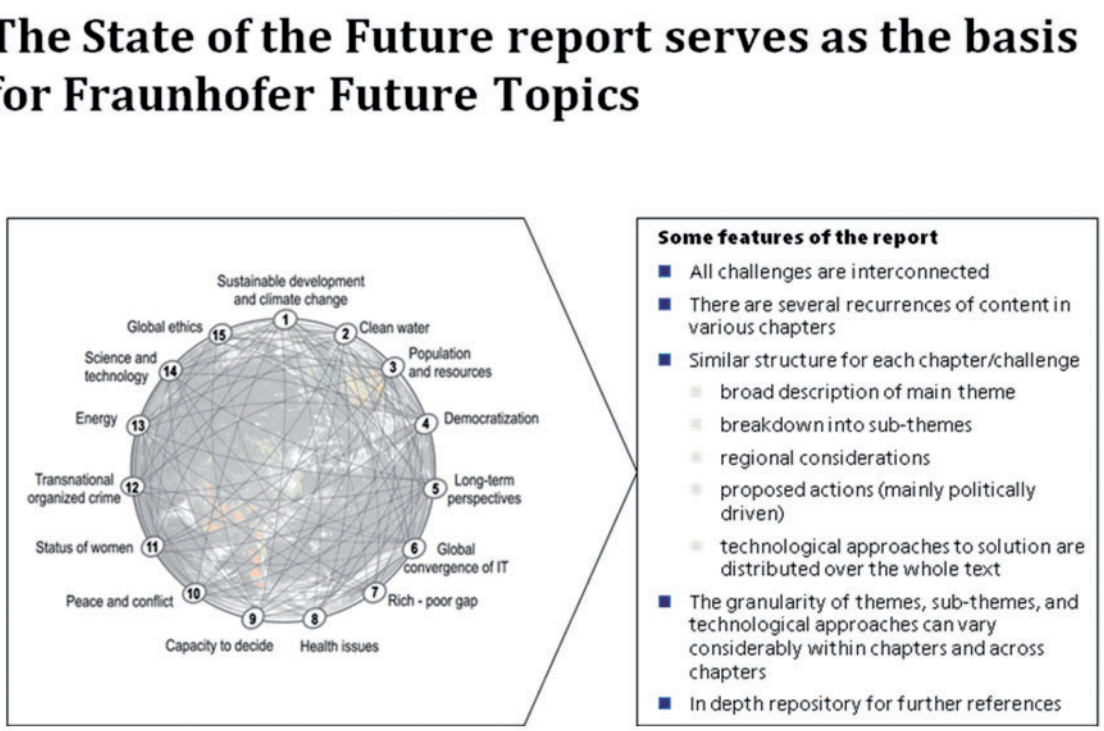

Figure 2. Challenges featured in the State of the Future report.

defined 15 global challenges. Each of the State of the Future challenges was discussed in great detail by a team in the Fraunhofer Society because not all of them could be the basis for research undertaken by the Fraunhofer Society.

The team selecting the grand challenges consisted of members from the headquarters in Munich and from the Fraunhofer Institute for Systems and Innovation Research in Karlsruhe.

In this first part of the process, mainly politically driven proposed actions as well as technological approaches to solutions of the challenges were identified from the State of the Future report, then described and discussed. The State of the Future Report was chosen because it is an established reporting system that is provided by the World Federation of UN Associations. 280 international experts from 32 teams contribute to the surveys it is based on. It has an in-depth description of challenges (more than 5,000 pages), a description of technological solution approaches and an annual adaptation of content. The 14th issue (Glenn et al. 2009) was used.

The following process steps were performed to distill specific Fraunhofer challenges from the report:

(1) *Selecting suitable global challenges and breaking them down into suitable subchallenges and their associated drivers* (see Figs 3–6: a Fraunhofer team of generalists assessed all challenges defined in the report. Only challenges where technological solutions were applicable (e.g. How can growing energy demand be met safely and efficiently?) were selected for further processing, others (e.g. How can the changing status of women help improve the human condition?) were dismissed. The chosen challenges were broken down into subchallenges and their drivers according to the report.

(2) *Extracting and evaluating technological solution approaches for each subchallenge* (see Figs 3, 4 and 6): the generalist team extracted the technological solution approaches mentioned in the text for each subchallenge. Each technological solution approach was rated in terms of its fit with the Fraunhofer R&D portfolio and clustered into solution fields.

(3) *Generating a long list and selecting five appropriate Fraunhofer challenges from it:* in a series of workshops, the generalist team, together with additional Fraunhofer experts, drafted a long list of Fraunhofer challenges by combining the subchallenges of step 1 and solution field with sufficient Fraunhofer fit of step 2. Each head of the above-mentioned groups of institutes was asked to prioritise the entries in the long list. With this input, the generalist team formulated the final list of Fraunhofer challenges (see Figs 5 and 6).

To summarise the process (see Fig. 6), it can be stated that the guiding principles when designing and performing the process were to:

- Find the right challenges for Fraunhofer: look at global challenges and ask which of them are crucial

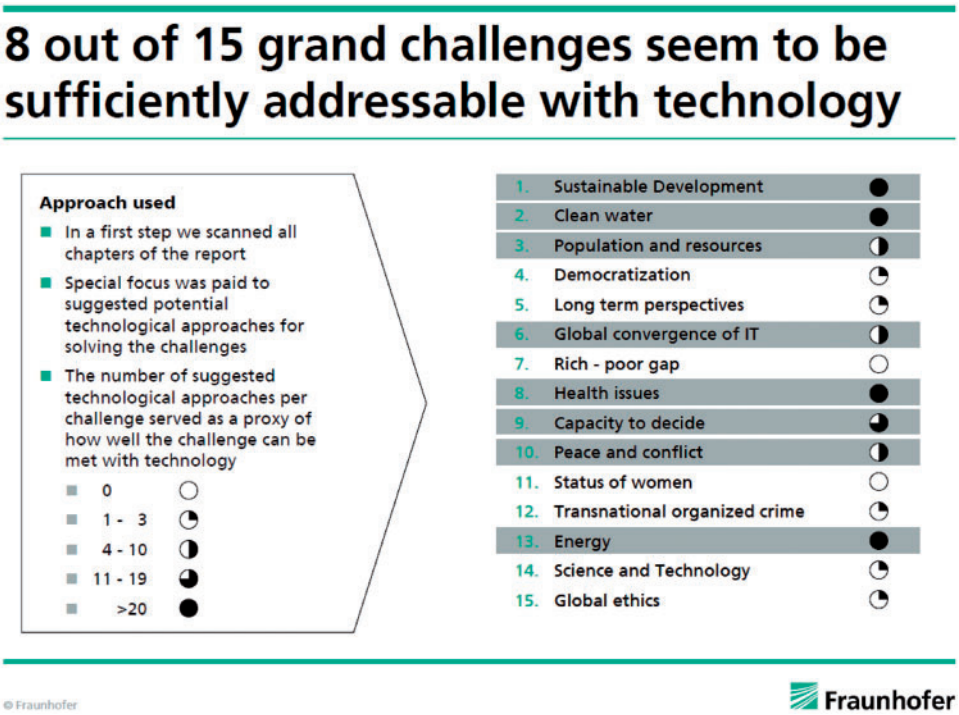

Figure 3. Assessment of grand challenges according to a set of Fraunhofer criteria.

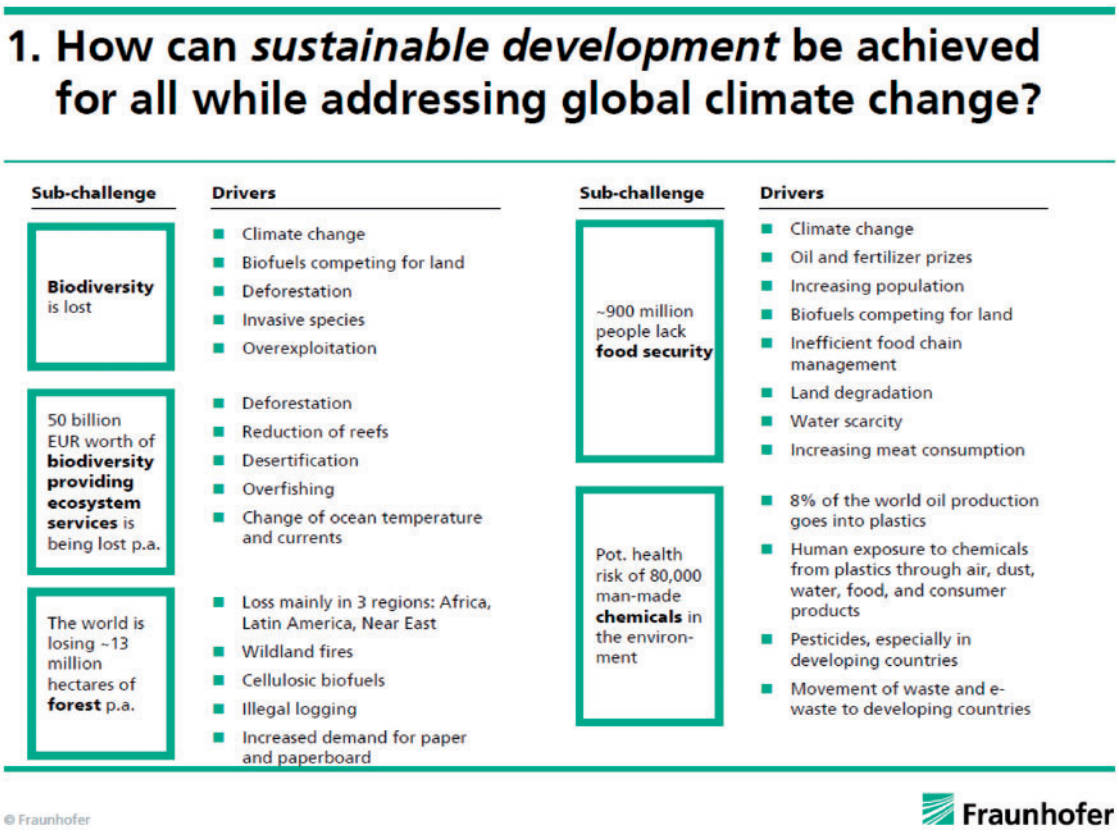

Figure 4. Example of identification of subchallenges and drivers.

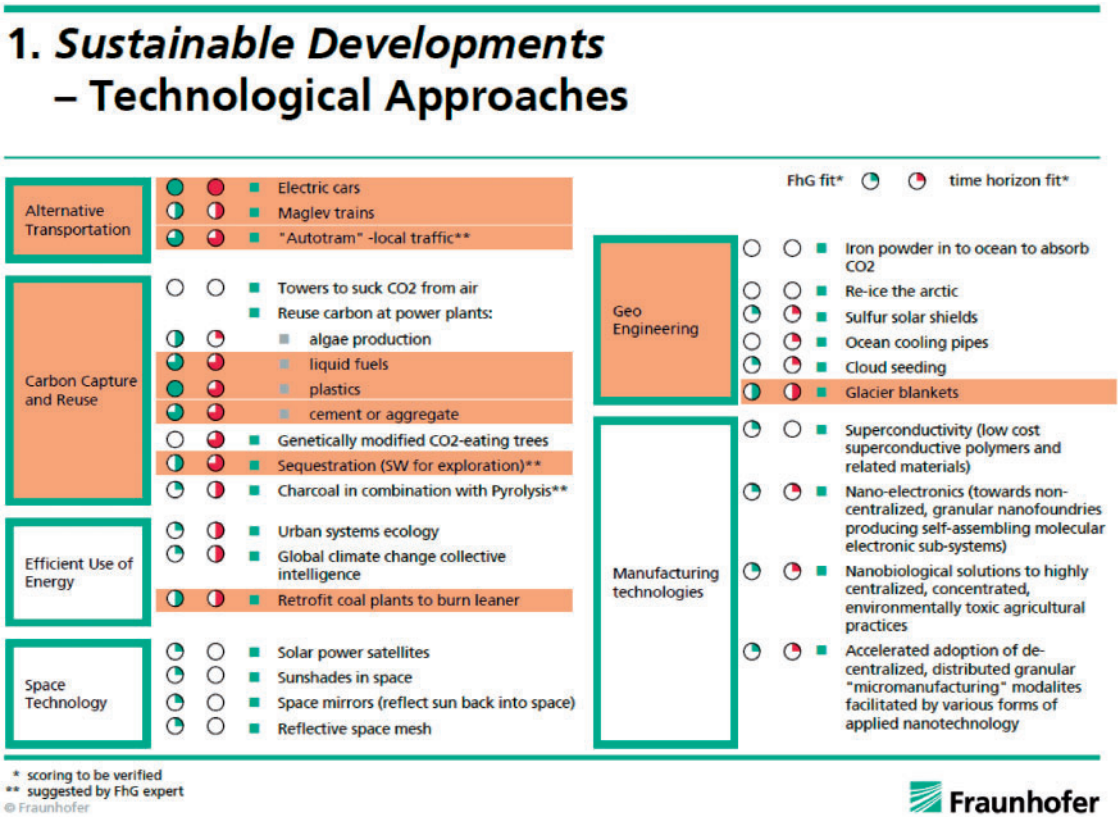

Figure 5. Example of assessment for subchallenges and technological approaches.

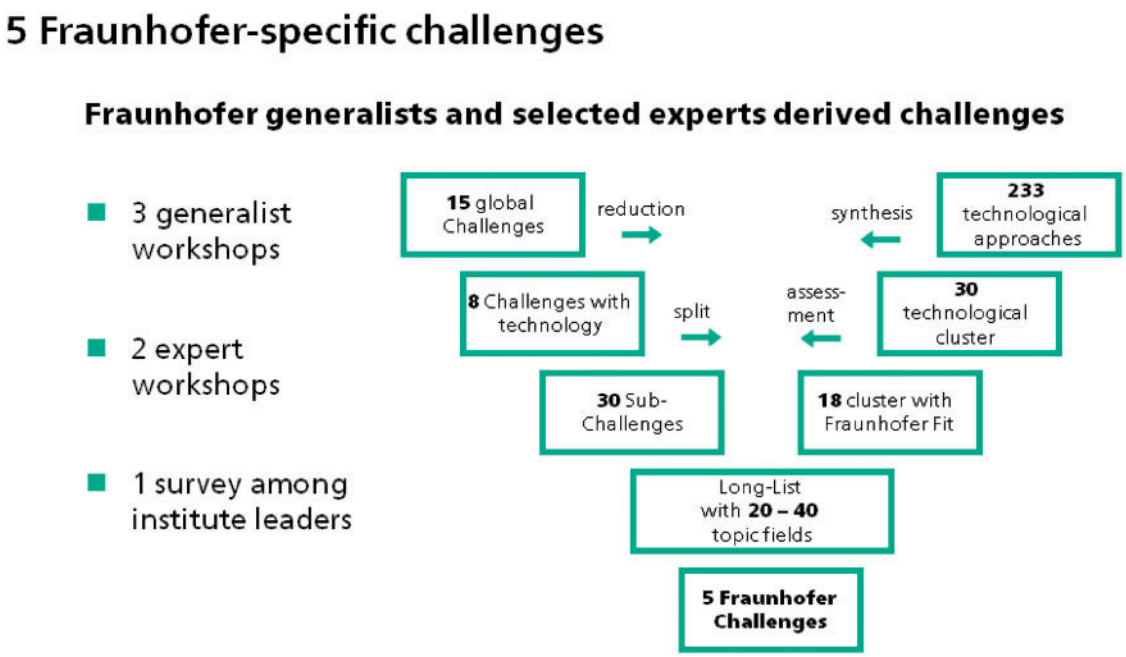

Figure 6. Overview of entire process.

for Fraunhofer or should be tackled with Fraunhofer projects.
- Involve the intellectual resources of many Fraunhofer scientists: include different people from Fraunhofer in the process so that in the end there is support for the future Fraunhofer projects.
- Bring together different knowledge domains: the projects that should be funded are not supposed to be technology-driven, but should bring together different disciplines and backgrounds in order to solve problems.
- Perform dedicated technological R&D projects: the projects should be supported by technologies from Fraunhofer and need to produce results that really offer a solution for a part of the problem.
- Ensure broad acceptance through a transparent process: the process is performed in an open and transparent way so that every institute has a chance to apply and participate. This is necessary for acceptance.

4.3 Dedicated projects to tackle the challenges

The Fraunhofer challenges served as a framework for an internal competitive call. A programme was defined in which institute consortia consisting of at least four institutes could propose collaborative projects to tackle the challenges. They had to explain their understanding of the challenge and which aspect of the challenge their project would provide a solution for. The anticipated impact of the project on the challenge had to be quantified, as well as the market potential for Fraunhofer that would be opened up through the project.

A jury consisting of senior Fraunhofer experts and external experts evaluated the proposals. The most convincing proposals received substantial funding for three years. A second round of calls was successful so that three additional projects could be started. All projects are still running.

5. Results: Challenges and projects

5.1 Five Fraunhofer challenges

Out of the 15 global challenges in the report, eight were assessed as being applicable to technological solution approaches and were broken down into 30 subchallenges. Within the 30 subchallenges, 233 technological approaches were extracted and synthesised into 18 solution fields with the appropriate Fraunhofer fit. The long list had 20 potential Fraunhofer challenges from which the five Fraunhofer challenges were generated:

- *energy*: low-loss generation, distribution, and utilisation of electrical energy
- *health care*: affordable health
- *environment*: life-cycle production
- *mobility*: reliable, low-emission mobility in urban areas
- *security*: detection and handling of disasters

5.2 Dedicated projects: First impact

More than 130 Fraunhofer research teams participated in a first call and provided project ideas (see Fig. 1). Full project proposals were submitted by 20 consortia. The consortia had five months to formulate their project proposals. The evaluation panel consisted of senior Fraunhofer scientists and external experts.

€5 million in funding for each challenge within the Future Markets programme are to be spent (starting in 2011). The criteria for the selection of the projects were:

- impact of the results on the challenge
- market potential for Fraunhofer Society

At least four different institutes need to be involved in each project. There are three years to execute the projects. In the end, a 'result' has to be presented.

The jury selected five convincing projects addressing three Fraunhofer challenges:

- *Energy*: low-loss generation, distribution, and utilisation of electrical energy:

(a) SuperGrid: components and systems for DC coupling of generators, storage and consumers in the European–African network
(b) hybrid energy storage for cities: integration of renewable energy, low-loss energy distribution and efficient use of energy by hybrid local network storage systems

- *Health care*: affordable health

(a) SKIN HEAL: development and evaluation of new therapies for chronic skin diseases
(b) SteriHealth: reducing the potential infection in hospitals, doctor's offices and care of the aged by new technologies for highly efficient on-site sterilisation

- *Environment*: life-cycle production

(a) molecular sorting: molecular sorting for resource efficiency

None of the project proposals that focussed on mobility and security were successful in the first call (see Tables 3 and 4). Hence a second call was initiated which led to three additional projects in mobility and security.

6. Discussion and lessons learnt

6.1 FTA-approaches of other research and technology organisations

From an R&D management programme that is organised by international institutes with a similar background to Fraunhofer, we know that other research and technology organisations in Europe have their specific approaches to

Table 2. Megatrends in society, environment and economy

Globalisation/localisation	(And lack of control) of trade, capital and terrorism; shift to Asia, migration flows to Europe, urbanisation—a cocooning effect to re-orient more towards local region
Demographic change	Increased life expectancy, population ageing and fewer children in Western world, rising world population in Asia and Africa
Knowledge society	Increase in knowledge-intensive services, commodity knowledge, digital divide
Changing values	Pluralism of lifestyles, individualisation and disintegration of traditions, staging his own biography, increasing significance of virtual communities
Dynaxity (dynamics + complexity):	Complexity and networking in business and everyday life increase
New production organisation	Increasing number of networks, increased cooperation, flexible cooperation along value chain, recycling, mass customisation
Change in work	Individual is a lifetime entrepreneur, time and location flexibility, and mental flexibility necessary (life-long learning), greater importance of women in business and society
Increasing mobility and transport	Due to increasing global flows of goods and leisure
Increasing energy consumption results in resource depletion	The development of alternative energies, revival of nuclear energy, decreasing consumption of resources
Climate change	Slowing climate change through political processes, additional stress caused by population growth and wealth in emerging markets, protection from consequences
Increasing conflicts within states	Global governance will be sought

Table 3. Proposals and teams

	Round 1		
Challenge	Project ideas	Selected projects	Teams involved
Mobility	5	0	28
Health care	8	2	40
Energy	6	2	32
Security	1	0	13
Environment	5	1	24
Sum	**25**	**5**	**137**

Table 4. Second Round

	Round 2		
Challenge	Project ideas	Selected Projects	Teams involved
Mobility	6	tbd	35
Disasters	12	tbd	59
Sum	**18**	**tbd**	**94**

defining their R&D portfolio. All institutions that are part of this network are rather independent in this definition. To give some examples:

- The Dutch research organisation, TNO, has a strong relationship with the Dutch government. Therefore, they have to discuss their portfolio plans with the relevant Dutch ministries. A four-year strategic plan is defined in an interactive manner with the ministries. The plan fixes the direction for the coming years. The theme lines of the strategy plan are then developed in top-down processes. In addition, TNO has 'enabling technologies' programmes.
- VTT, the Finnish research organisation, has a rather centralised research and technology development portfolio development. Although VTT is a governmental agency and is partly funded by the government, the government itself is not involved in the portfolio planning, but target agreements have to be negotiated every year. VTT distributes basic funding to their different areas in order to support cross-knowledge cluster projects. For strategic directions, VTT defines some broad themes of research, but the process is rather informal. The single research units are then able to apply for money from the central units to finance their different projects.
- SINTEF is the largest independent research organisation in Scandinavia. It is also searching for 'practical solutions'. SINTEF is an independent, non-commercial organisation investing the profits of its projects in new research, scientific equipment and competence development. SINTEF does not have a formal process for defining tts overarching topics. The SINTEF research and technology development portfolio is defined at the level of the single institutes. This means that their focus is not on providing overall large solutions to the grand challenges.

To date, none of these research organisations has tried to orient itself towards global challenges. Therefore, the Fraunhofer experiment is unique among independent research institutions.

6.2 Impact of the Fraunhofer future-oriented process

The FTA process described in this paper produced dedicated research projects, in which teams from different Fraunhofer knowledge domains worked towards

technological solutions for Fraunhofer-specific challenges. For the first time, Fraunhofer used a topical framework for an internal funding programme. A necessary prerequisite for acceptance by the institutes is a sound and transparent method in selecting these topics.

The five research projects that were selected started in 2011, so it is too early to evaluate their concrete impacts. Nevertheless, all the projects are expected to address a small part of a global challenge and to try to contribute to solving the problems. For Fraunhofer, with its strong technology- and at the same time application-orientation, this is rather new. The change from proposing a technology-driven cooperative project to a problem-driven is sometimes underestimated. Normally, a researcher applies for a project with a proposal based on technology-oriented programmes. If his/her competence fits with the working programme, he/she acts as a nucleus and invites other researchers to build a consortium in order to broaden the scientific approach. However, problem-oriented proposals require more general thinking, e.g. about the impact aspect. Which result leads to a maximum impact in solving the problem? A single researcher with one core competence is often not able to have an overview of the spectrum of alternative solutions. Therefore a communication platform has to be offered, in which researchers from different disciplines discuss possible ways in which to obtain the most effective solution. As soon as such a topic is found, the most appropriate consortium will be chosen to carry out this project.

With this top-down and bottom-up approach, a learning process was started towards needs-oriented thinking across the institutes. Through the collaborative and transdisciplinary problem-solving approach, an awareness of the sustainability aspects was raised within Fraunhofer. A broad communication of the programme within Fraunhofer commenced. More than 230 Fraunhofer teams participated in the calls. 43 project proposals were intensively discussed. All of them already represent joint, interdisciplinary work beyond mere technological approaches. Therefore, the communication effect will go far beyond the mere projects. The connections and shared interests of the different researchers will lead to additional new ideas—and maybe projects sponsored by other parties.

A final effect occurred when the projects had already started: when really starting the work and going into detail, one of the winning consortia noticed that they needed competencies in the social sciences that they could not currently provide. When they applied, this was not yet known. So they had the idea of inviting another Fraunhofer institute (from one of the teams that applied but whose project was, for different reasons, not included in the list of winning proposals) to join their project in order to provide these competencies. Here, the new interdisciplinary approaches have already started.

6.3 Lessons learnt and outlook

Using global challenges as a starting point for an internal FTA process within the corporate strategic R&D planning was a new approach for Fraunhofer. As Fraunhofer is a highly decentralised organisation, this corporate process needs to be participative and transparent to receive broad acceptance among the many stakeholders (e.g. the Fraunhofer board, 60 institutes, 6 institute groups and 20 institute alliances). The combination of the top-down derivation of the specific challenges with the bottom-up generation of the specific technological solutions met this requirement well.

However, some lessons were learnt that should be kept in mind when executing such a process in this context, and which may even be helpful in other contexts:

- *Definition and detailed clarification of what is regarded as a global challenge*: as the international definitions vary to a large extent, each organiser of a process has to define for himself what has to be addressed under the heading of global challenge. Also, Fraunhofer was struggling with the different definitions and the 'three' variations of global challenges mentioned in Section 2 of this paper.
- *Granularity of the specific challenges*: the five challenges serving as a framework for the call had a very broad scope. This was because many stakeholders with different interests participated in deriving the challenges. In the end, they agreed on a broad compromise. The formulation of this compromise was therefore rather conservative and similar to the grand challenges of other institutions (see also Section 1 of this paper). However, more specific challenges would have helped to compare the proposed technological solutions.
- *Impact-orientation*: a goal of the competitive call was to find the most convincing collaborative solution Fraunhofer could provide for the specific challenge. Institute consortia were required to quantify the impact of the anticipated results of the projects. The careful analysis and illustration of the impact was indeed a hurdle for the proposal writer: it was difficult to quantify an estimated impact.
- *Moderation of problem-solving*: conceptually, the bottom-up generation of the solution approaches should induce collaborative problem-solving and was self-organised by the institutes. But in most cases, one single institute took the lead in the problem-solving with a certain technological focus and a solution concept. Other institutes were often involved quite late in the development and formulation of the problem-solving process. Central moderation of the problem-solving—as a kickoff of the application phase—is necessary in order to identify solutions with high impact and to foster collaborative aspects.

The authors of this paper were involved in the concept and practical application of the 2010 Fraunhofer future-oriented process. With this experience in mind, we expect this new demand-driven approach to have an impact on other Fraunhofer future processes: not single technologies, but system solutions seem to be the future framework for joint research programmes, not only at a European level but also at the Fraunhofer level. This already existing trend—and here a consistent timeline is meant as a 'trend'—will be strengthened by such processes.

As the projects which can be regarded as the results of this process are still running, it is too early to evaluate their effectiveness. But now we can already observe some new thinking in those teams who joined up to undertake such an endeavour. Changing minds and thinking by letting people realise their own ideas and projects—open in their ideas, but guided by the challenges that are lying ahead—applies not only apply to Fraunhofer but also to many other organisations.

Notes

1. See <http://www.hightech-strategie.de/de/81.php> accessed 15 July 2011. This is the strategy of the German government in science and technology fields, see also <http://www.bmbf.de> accessed 15 July 2011.

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