FET_TRACES

Tracing impacts of the FET programme

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Report: List of indicators and assignment of suitable methods

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About FET_TRACES

FET_TRACES is a research project for the European Commission which analyses and measures the impacts of the research funding scheme "Future and Emerging Technologies Open" (FET Open and FET Proactive). Within the European research funding landscape, the FET scheme acts as a pathfinder for new ideas and themes for long-term research in the area of information and communication technologies and beyond. Its mission is to promote high risk research, offset by potential breakthrough with high technological or societal impact (see http://cordis.europa.eu/fp7/ict/fet-open/home_en.html).

In the FET_TRACES project we will investigate and measure direct and indirect impacts of these two schemes on the science and technology landscape and its perception by individual researchers who are potential proposers for FET Open and FET Proactive projects. Results from innovation research will be used to develop a targeted indicator set covering central aspects of the FET mission (novelty, trans-disciplinarity, innovation-ecosystem). For the data collection we use sophisticated impact assessment methods like bibliometrics, patent analysis and online surveys. In addition to the impact assessment we will analyze selected breakthrough-projects to find out about necessary components for "breakthrough"-research. The study will also include insights from FET-like funders on national levels in Europe.

Terms of use

This document was developed within the FET_TRACES project (see www.fet-traces.eu), funded by the European Commission within Horizon 2020, by a consortium consisting of two partners, the Fraunhofer ISI in Karlsruhe, Germany (coordinator) and AIT Austrian Institute of Technology in Vienna, Austria.

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Contents

1 Introduction: Indicator development

This report describes the indicator development and selection of suitable indicators for the impact assessment of the Future Emerging Technologies (FET) programme. It provides a background of the goals of FET programme that are the basis for the indicator development and selection. The FET programme aims to go beyond what is known and to support visionary thinking that is expected to open up promising avenues towards powerful new technologies. The visionary aspects and exploratory characteristics of FET are challenging the indicator development. As the mission of FET is to turn Europe's excellent science base into a competitive advantage, FET combines a variety of goals and approaches. The indicator development draws from the characterization of FET-research in our conceptual paper (D1, see www.fet-traces.eu/traces/).

According to its self-description, the FET programme of the European Commission has the following aims:

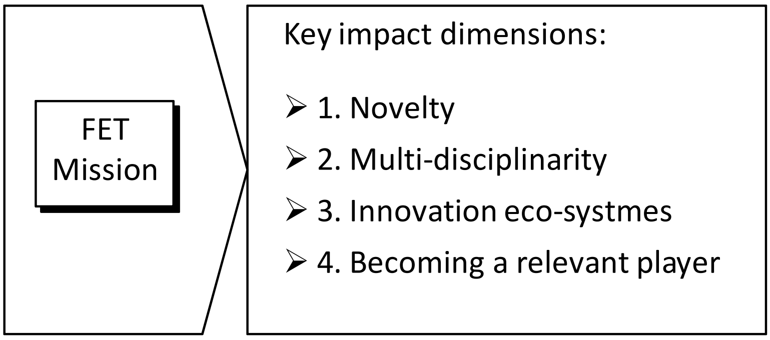
- FET Open funds projects on new ideas for radically new future technologies, at an early stage when there are few researchers working on a project topic. This can involve a wide range of new technological possibilities, inspired by cutting-edge science, unconventional collaborations or new research and innovation practices.[1]
- FET Proactive nurtures emerging themes, seeking to establish a critical mass of European researchers in a number of promising exploratory research topics. This supports areas that are not yet ready for inclusion in industry research roadmaps, with the aim of building up and structuring new interdisciplinary research communities. [2]

These aims translate into the three key impact dimensions “Novelty”, “Multi-disciplinarity”, and “Innovation eco-systems”. In addition to assessing the impacts of the FET programme, we are looking for ways to increase the footprint of this special research funding programme. Thus, a fourth impact dimension in our study is “Becoming a relevant player” (see figure 1).

[1] Source: FET-Website 2016, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies

[2] Source: FET-Website 2016, https://ec.europa.eu/programmes/horizon2020/en/h2020-section/future-and-emerging-technologies

Figure 1: Key impact dimensions of FET Open and FET Proactive



We can describe the key impact dimensions for assessing the FET programme in the following way[3]:

1. Novelty: At the centre of FET are novel ideas, concepts, and approaches which may lead to radical new technologies. The keywords in the mission statement to characterize this aspect are "visionary", "foundational", "transformative", "high-risk", "long-term" and "technological innovation".

2. Multi-disciplinarity: Multi-disciplinary approaches and collaborations across disciplines are the second key dimension of projects funded within the FET programme. This includes the claim that not only neighbouring disciplines or research fields already closely linked together (narrow interdisciplinarity) are supported, but that disciplines not related to each other at first sight may collaborate in FET projects (wide interdisciplinarity). The keywords in the mission statement to characterize this aspect are "collaborative" and "across disciplines".

3. Innovation eco-systems: FET-projects shall start new economic activities based on the new technology or concept developed in the project. Apart from the scientific uptake, this includes industrial activities of any kind (company R&D, spin-offs, patent applications, etc.). The keywords in the mission statement to characterize this aspect are "technological innovation" and "visionary" as well as "SME-involvement", and "technology focus".

4. Becoming a relevant player in the funding landscape: This dimension is indirectly related to the impact assessment of this study. The FET programme supports a specific way of doing research and developing new technologies and consequent-

[3] For more details see Deliverable D1 of FET_TRACES, p. 6f.

ly has a special position within the European research funding landscape, for example vis-à-vis the European Research Council (ERC) or Marie Skłodowska-Curie Actions. Although the FET programme has been enlarged in scope and increased in budget in recent years, it is still a comparatively small programme and not every researcher in Europe knows of its existence. The conviction of the FET programme makers that this kind of research funding yields exceptional results (and thus shall be more prominently positioned within the European funding landscape) is also reflected in literature which analyses the novel connections between knowledge and applications (see for example Etzkowitz & Leydesdorff, 2000; Nowotny, Scott, & Gibbons, 2003). Thus, in this project, we are looking for strategies to increase the footprint of the FET programme within the European research. “Footprint” is used in a broad sense and means the level of awareness, the participation of the best researchers, and the impact within the scientific and industrial R&D communities.

This multidimensional impact assessment approach indicates that different aspects have to be taken into account. Based on the above structuring and the results of the conceptual workpackage (D1) we have developed indicators and assigned suitable methods to each indicator. The results are presented in the table in the following section.

2 List of indicators and assignment of suitable methods

Table 1: List of indicators in dimensions and assignment of suitable methods

Indicator		*Method*
Novelty		
1	New topics: Percentage of FET projects dealing with topics that were not present in the scientific literature before	LDA-Analysis
2	Off-mainstream research ideas: Number of FET projects that were rejected before by other funding institutions	Survey
3	Uptake in science: Number of articles from FET-projects which are highly-cited by other researchers	Bibliometrics
4	Outstanding excellence: Major scientific awards received for FET-related research	Survey
5	Novel combination of approaches: Novel composition of the interdisciplinary consortia	Survey
6	New research avenues for established researchers: Number of researchers pursuing new research directions	Survey
7	Novelty of outcome: Answers of researchers about the novelty of their results	Survey
8	High impact scientific publications: Number of publications in *nature* and *science*	Bibliometrics
Multi-disciplinarity / Interdisciplinarity		
1	Input interdisciplinarity: Number of FET projects with project partners from different disciplines	combination of portfolio analysis and bibliometrics
2	Output interdisciplinarity: Number of projects with publications in different subject areas in the Web of Science	Bibliometrics

Innovation eco-systems		
1	Relevance I: Publications coming out of a FET project	Bibliometrics
2	Relevance II: Publications with industrial partners	Bibliometrics and survey
3	Community building I: Transfer of new ideas into the scientific and industrial R&D community - number of citations of FET-project related publications	Bibliometrics
4	Community building II: Dissemination of a new ideas and the genesis of new scientific communities – number of FET-related publications co-authored by researchers who were not involved in the original FET project	Bibliometrics and survey
5	Dissemination of FET ideas into industry: number of publications that are co-authored by researchers from industrial R&D not involved in the original FET project	Bibliometrics and survey
6	Economic relevance of FET project results: patent applications which relate to concepts developed in FET projects	Survey
7	Project families analysis: Number of FET projects which triggered other research proposals	Project family analysis, bibliometrics and survey
8	Communicating FET results to industry: Number of contributions to proceedings of conferences with industry involvement	Bibliometrics & Survey
9	Industrial relevance: contacts to industry & cooperation with companies	Survey
Becoming a significant player in the funding landscape		
1	Level of awareness and presence of the FET programme for researchers	Survey control group
2	Number of non-FET researchers saying that interdisciplinary, technology-oriented research projects support their academic career	Survey control group
3	Number of FET-participants saying that interdisciplinary, technology-oriented research projects support their academic career	Survey

3 Indicator dimensions and indicators in detail

3.0 Novelty

There is significant and growing interest in the emergence of novel technologies and in research that is expected to result in novel technologies from the perspective of STI policy. What novelty in research is, lack key foundational elements, namely a consensus on what classifies research as novel. Basic research projects are often seen as novel as such, but the notion of novelty used in the context of FET and similar approaches such as transformative research aim at a more radical concept of novelty. This concept of a kind of radical novelty can be approached indirectly by focusing on attributes and characteristics of this specific form of novelty. The framework for operationalising novelty will then be elaborated on the basis of the proposed characteristics and attributes.

With regard to FET projects we will analyse different levels of (radical) novelty and/ or different dimensions of novelty that we can better specify after the first analysis.

- *Radical novelty* is characterized by the attribute that the idea was not present in the scientific community before a specific FET project brought it up.
- *Combinatory novelty* is characterized by the specificity that the general topic, technology, method, approach might have been discussed in scientific communities before, but the specific combination has not been explored previously.

The crucial question is how to analyse radical novelty especially in the area of interdisciplinary research. A research project can be seen as highly novel from the perspective of a discipline because it goes beyond existing approaches while others may see the same project as an expected extension of an existing body of research. Also, novel research projects are often grouped together under ‘umbrella terms’ (e.g. complex systems, nano-electronics, synthetic biology), even if they might be more adequate treated separately given their different novelty related features (e.g. ideas, theories, combination of methods, technological aims).

As FET aims at new technologies, novelty can also be related to the technology: Novelty is not only a characteristic of technologies deriving from radical scientific breakthroughs but may also be generated by putting an existing technology to a new use (c.f. Rotolo, Hicks, & Martin, 2015). In that sense, ‘relative’ novel research approaches (those not characterised as radically new ideas) can also be radically novel in research fields different from those where ideas, concepts or methods were initially developed.

With regard to emerging technologies, radically novel can be that technologies may fulfill a given function by using a different basic principle as compared to what was used before to achieve a comparable purpose. In retrospective analyses, citation and co-word analyses can be used to identifying radical novelty. Data of a broader defined field can be exploited to map the networks of a knowledge domain over time. Citation analysis can be used

- to identify citation patterns among documents to generate a network in which nodes are documents and links between nodes represent a direct citation between two documents (direct citation analysis),
- to analyse the extent to which two documents are cited by the same documents (co-citation analysis)
- analyse to what extent two documents cite the same set of documents (bibliographic coupling)

Co-word analysis can use the content of documents to create a network of keywords (or key phrases) that are linked according to the text to which they co-occur across the set of selected documents (Rotolo et al., 2015, p. 1835).

In FET_TRACES, we will use quantitative as well as qualitative methods to assess the novelty aspect of funded FET-projects: For the quantitative analysis we will use a special bibliometric method called LDA-analysis (Mund, 2014). Our qualitative approach relates to the survey in which we will ask researchers about their perception of the specific novelty in their project. We will ask them what they consider as new in the project, what they consider as radical new and what they consider as characteristics of (radical) new approachs in research. As Wagner and Alexander (Wagner & Alexander, 2013, p. 191) indicate, possible answers could be: new tools, techniques or new equipment were developed.

Novelty is not the same as success. A FET-project could be dedicated to a radical novel idea, but might turn out to be not successful at all. This requires to reflect on the definition of “success”. Usually, an idea is seen as successful when it is highly cited by other researchers. The relation between novelty and success will be analysed as part of the impact analysis in comparing the results of the different indicators for novelty.

3.0.1 Indicators for the measurement of novelty

3.0.1.1 New Topics: Percentage of FET projects dealing with topics that were not present in the scientific literature

The first indicator for novelty is the percentage of FET projects dealing with topics that were not present in the scientific literature in the preceding time period. With this indicator we will measure the level of novelty of ideas, concepts, and approaches in FET projects. We will use LDA-Analysis (Mund, 2014) as method.

"Novelty" can be incremental or disruptive in a Kuhnsian sense. The article by Wagner and Alexander (Wagner & Alexander, 2013) advised us that this kind of research may lead only to a small extent to radically new research results and will mostly comprise of small-step-improvements, which Kuhn would label as "normal" science. However, it was noted that truly exceptional breakthrough-research requires a mass of "normal" science in its background to finally succeed with the one genuine new idea.

In general it can be said that many publications from a project as well as many citations of these publications indicate that something really new was done. As described in our conceptual framework, there may be time-lags to be considered. Also, publications in which the basic idea is developed are usually cited by other researchers more often than publications which report of small technical improvements because these might be so specialized that only a small group of researchers is actually active in the respective field.

To find out the level of novelty of FET-projects we will proceed as described in the FET-TRACES proposal on pages 23-25 (LDA-analysis).

Preparatory work for the LDA-analysis includes that we identify one or two early articles which reflect the idea of the project by looking at the publication list to be found at the project website and the abstract of the project. Alternatively, we will try bibliometric approaches to identify central publications. We will exclude proceedings and only cover journal articles because proceedings usually have shorter reference lists. Bibliometric coupling compares the corpus of cited researchers in a given article and calculates levels of similarities using this information. Also, foundational ideas are more likely to be published in journal articles than in proceedings. Proceedings are more likely used by researchers to report of small changes and to discuss and enrich these with inputs and contributions found at the respective conferences.

In order to identify the relevant FET-publication we need the publication list of the respective FET-project. The list is available from the FET-project Websites. Currently we have identified websites of 125 FET-projects from our sample. A total of 74 do not have a website anymore. Of these 74 we have the name and e-mail-address of the scientific coordinator of 42 FET-projects (all FP7). From the remaining 32 projects we currently do not have the name or contact address of the coordinator. Some missing address data might become available from other sources we are currently testing.

A second piece of information required for the LDA-analysis is the classification of the journal in which the article was published. For this we will use the classification scheme of the Web of Science, a list of 5 pages containing 242 single classifications ranging from "Acoustics" to "Zoology". This information will also be used to define the level of output interdisciplinarity.

We will check whether or not an idea followed in a FET-project (as reflected in an early publication to be selected) was a subject of discussion in a different publications in a 3-year-period prior to the publication of the FET-article. As a result we will know how many FET-projects have followed radical new approaches and how many FET-projects have picked up on ideas already under way in the scientific community.

3.0.1.2 Off-mainstream research ideas: Number of FET projects that were rejected before by other funding institutions

The next indicator for novelty is the number of FET projects that were rejected before by other funding institutions. The rejection of proposals that were finally successful in the FET programme may be one factor indicating off-mainstream research ideas. To identify these projects the survey will be used.

Following Wagner and Alexander (Wagner & Alexander, 2013, p. 192) we may ask the following questions in the survey:

"Has a version of your FET-project idea been rejected prior to the FET-project? (Yes/no). If yes, please speculate about the reasons why the idea was rejected (multiple answers possible):

- Because the proposed research idea was too 'high risk' or too new in the view of the review panel;
- Because the proposed research idea required interdisciplinarity work which the review panel did not appreciate;
- Because the proposed research idea countered a conventional paradigm."

3.0.1.3 Uptake in science: Number of articles from FET-projects which are highly-cited by other researchers

Based on the assumption that novel ideas will be taken up in a dynamic way in today's technology-oriented research communities, the number of articles from FET-projects which are highly cited by other researchers will be used as an indicator. The method to identify these articles is bibliometrics.

One or two early publications reflecting the respective FET-idea will be selected for each project in order to calculate citation rates. The respective FET-publication will be identified using the Web of Science-database and cross-checked by consulting the publication lists available from the FET-project websites.

In general, the use of bibliometric measurements of impact is limited. Bibliometric impact factors are used in making decisions ranging from selecting journal subscriptions to deciding tenure cases and they are also used in allocating research funding and measuring impact of funding programmes. However, with regard to high-risk research, journal impact factors may have limited significance. Impact factors vary widely across academic disciplines (Althouse, West, Bergstrom, & Bergstrom, 2009) and it is unclear how radical new topics are in general integrated into established journals. Another problem is that the use of data of the Thomson Scientific Web of Science is in itself problematical because of the limited transparency of a for-profit company like Thomson Scientific (Brumback, 2008).

3.0.1.4 Outstanding excellence: Major scientific awards received for FET-related research

The number of FET researchers and coordinators who received major scientific awards for their FET-related research will be used as another indicator. The assumption behind this indicator is a close relationship between excellence and novelty. The method to be used for this indicator is the survey.

3.0.1.5 Novel combination: Novel composition of the interdisciplinary consortia

Novelty in research is often the result of the combination of approaches, tools and methods that are new in a specific research field. Therefore, the novel composition of the consortium will be used as indicator. Questions about the consortia will be part of the survey.

The survey will integrate the following questions about the composition of the consortia:

- Was the consortium a completely new combination or was it compiled of partners who were cooperating before?
- If partly/partly: Were there completely new partners in the project which none of the partners have worked with before?

This question aims to find out whether the FET-idea was generated in the context of a conference where researchers meet other researchers and potentially team up to write a proposal to follow up on ideas generated at the conference. This implies a notion of actively networking researchers, contrary to the notion of the individual genius sitting alone in his room creating new ideas. Research is increasingly seen a collaborative effort (c.f. He, Geng, & Campbell-Hunt, 2009; Heinze & Kuhlmann, 2008; Hoekman, Frenken, & Tijssen, 2010; The Royal Society, 2011; Wehrens, Bekker, & Bal, 2011) which requires people to meet at conferences and stay connected and collaboration is therefore a goal of many funding programmes (Ubfal & Maffioli, 2011).

3.0.1.6 New research avenues for established researchers: Number of researchers pursuing new research directions

This indicator will measure the number of researchers pursuing new research directions. The assumption behind is, that FET allows mid-career researchers to try out new avenues. It enables outstanding researchers with a proven scientific track record to pursue exceptionally innovative or high-risk projects because FET-funding allows to take their research in new directions. This approach is underlying the transformative research funding in the US, “to help mid-career researchers to branch into an exploratory area of research” (Wagner & Alexander, 2013, p. 196). The method to identify researchers for this indicator is the survey.

3.0.1.7 Novelty of outcome: Answers of researchers about the novelty of their results

To identify the novelty of results and project outcome we will ask researchers about the novelty of their results. What was the most remarkable scientific or technological outcome of the FET-project? Was a portion of it unplanned? The method to identify these outcomes is the survey.

We will use an open question in the survey to gather topical input for the impact assessment. If breakthroughs were really achieved, this would be the question where coordinators could report of it. Also, the answers could cover unintended outcomes which cannot be identified otherwise.

3.0.1.8 High impact scientific publications: Number of publications in ***nature*** and ***science***

To identify potentially high impact scientific publications, the number of publications resulting from FET projects in "nature" and "science" will be identified. We will use bibliometric tools to identify these publications. Despite the conceptual difficulties which put some limits to the interpretation of this indicator, it can be considered that this indicator is useful for the overall impact measurement. It represents mainly excellence and excellent network building capabilities and is part of researcher´s strategies to make their research known to a wider public.

3.1 Multi-disciplinarity / Interdisciplinarity

Considering the complexity of world problems and global societal challenges, it seems evident that ways of tackling them do not fit straightforwardly into disciplinary frameworks. That is the background why concepts of cross-/inter-/multi-/trans-disciplinary research have gained increasing attention in science policy. The concept is also underlying the FET approach. Interdisciplinary research is seen as "the way to go" and the expectations are high with regard to the beliefs that the breakthroughs disproportionately take place at the interstices between disciplines. This is the case even if findings from bibliometrics suggest that science is indeed becoming more interdisciplinary, "but in small steps – drawing mainly from neighboring fields and only modestly increasing the connections to distant cognitive areas" (Porter & Rafols, 2009, p. 720). As FET is addressing specifically interdisciplinary and collaborative research, we expect a much higher degree of interdisciplinarity than in scientific research in general. The purpose of interdisciplinary research from the perspective of the FET programme is to advance fundamental understanding to address future challenges whose solutions are beyond the scope of a single discipline or field of research practice.

The FET schemes focus on multi-disciplinary approaches and collaborations across disciplines. Within the FET programme, the concept of multidisciplinarity is specified, stating that the "FET actions are expected to initiate radically new lines of technology through unexplored collaborations between advanced multidisciplinary science and cutting-edge engineering". This is seen as a backbone that „will help Europe grasp leadership early on in those promising future technology areas able to renew the basis for future European competitiveness and growth, and that can make a difference for society in the decades to come“ (see FET website at https://ec.europa. eupro-grammes/horizon2020/en/h2020-section/fet-open).

Regarding the measuring the interdisciplinarity, it is concluded that fundamental questions of knowledge integration and desired outcomes need to be addressed before interdisciplinarity can be measured in a way that meet policy and research needs (Wagner et al., 2011). What are the institutional contexts and kind of research processes that foster knowledge integration in research? How can the level of inter- and multi-integration be identified, measured, and linked to the very specific outcomes, high-risk research is aiming at?

Crucial in answering these questions[4] is to follow the interdisciplinarity of knowledge input on the one hand, and the interdisciplinarity of the published outputs that reflect the integration of interdisciplinarity in the research process on the other hand.

3.1.1 Indicators for Inter-/Multi-disciplinarity - Overview

3.1.1.1 Input interdisciplinarity: Number of FET projects with project partners from different disciplines

This indicator will identify the number of FET projects with project partners actually being from different disciplines and research fields (inter- or transdisciplinary) rather than from neighbouring fields of research (multidisciplinary). This indicator has to be specified according to the data available and to be combined. For the FP7 FET projects a reasonable proportion of disciplines can be identified through the addresses of the partners involved as many addresses of the involved researchers are addresses of specific institutes and not only addresses of universities and national umbrella organisations. For the FP6 projects the affiliations of authors will be used to identify a reasonable number of institutes and research clusters and therefore indirectly to identify disciplines. Alternatively, the different research fields listed in the Web of Science database for an early central FET-publication may be used to define which disciplines were involved in this specific FET-project.

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[4] The indicators of interdisciplinarity differ highly in recent discourses; c.f. (Huutoniemi, Klein, Bruun, & Hukkinen, 2010; Leydesdorff, 2007; Leydesdorff & Rafols, 2011; Pei & Porter, 2011; Ponomarev, Lawton, Williams, & Schnell, 2014; I. Rafols, Leydesdorff, O'Hare, Nightingale, & Stirling, 2011; Ismael Rafols & Meyer, 2010; Roessner, Porter, Nersessian, & Carley, 2013; Sugimoto, 2011; Sugimoto, Ni, Russell, & Bychowski, 2011)

The team's interdisciplinarity is in indicator for the broad input of a variety of tools and knowledge from different disciplines into the project. This kind of 'input interdisciplinarity' will be measured by analysing the partners of the participating institutions of a FET-project. This procedure implies fuzziness because of the recent level of interdisciplinarity in academia today. Two main levels are possible: The level of departments and institutes involved in the projects or the level of researchers involved. We might identify interdisciplinarity with regard to the departments involved, but mainly researchers from neighbouring disciplines. Or the other way round: We might find a project only integrating neighbouring disciplines at the level of institutes, but researchers from a broad variety of disciplines working in these departments or institutes. Because of the data available that can be indirectly extracted we will use the data about the discipline and/or research field that is indicated by the terms related to institute/affiliation (c.f. Institute of Physics, Institute of Robotics).

To compare the interdisciplinarity of the knowledge that is integrated in the project consortium (input interdisciplinarity and the level of interdisciplinarity in the publications (output interdisciplinarity) systematically, the Web of Science classifications will be used.

3.1.1.3 Output interdisciplinarity: Number of projects with publications in different subject areas in the Web of Science

To identify the output interdisciplinarity we will identify the number of projects with publications in different subject areas in the Web of Science. The methods used are bibliometrics and case studies for a qualitative assessment of the level of interdisciplinarity. For the analysis of the results we will analyse in how many research areas the publications appear.

Categories & Research Areas

Research areas are classified into five broad categories [5]:

- Arts Humanities
- Life Sciences Biomedicine
- Physical Sciences
- Social Sciences
- Technology

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5 http://images.webofknowledge.com/WOKRS522R4/help/WOS/hp_research_areas_easca.html

Life Sciences & Biomedicine	**Physical Sciences**
Agriculture	Astronomy & Astrophysics
Allergy	Chemistry
Anatomy & Morphology	Crystallography
Anesthesiology	Electrochemistry
Anthropology	Geochemistry & Geophysics
Behavioral Sciences	Geology
Biochemistry & Molecular Biology	Mathematics
Biodiversity & Conservation	Meteorology & Atmospheric Sciences
Biophysics	Mineralogy
Biotechnology & Applied Microbiology	Mining & Mineral Processing
Cardiovascular System & Cardiology	Oceanography
Cell Biology	Optics
Critical Care Medicine	Physical Geography
Dentistry, Oral Surgery & Medicine	Physics
Dermatology	Polymer Science
Developmental Biology	Thermodynamics
Emergency Medicine	Water Resources
Endocrinology & Metabolism	**Technology**
Entomology	Acoustics
Environmental Sciences & Ecology	Automation & Control Systems
Evolutionary Biology	Computer Science
Fisheries	Construction & Building Technology
Food Science & Technology	Energy & Fuels
Forestry	Engineering
Gastroenterology & Hepatology	Imaging Science & Photographic Technology
General & Internal Medicine	Information Science & Library Science
Genetics & Heredity	Instruments & Instrumentation
Geriatrics & Gerontology	Materials Science
Health Care Sciences & Services	Mechanics
Hematology	Metallurgy & Metallurgical Engineering
Immunology	Microscopy
Infectious Diseases	Nuclear Science & Technology
Integrative & Complementary Medicine	Operations Research & Management Science
Legal Medicine	Remote Sensing

Life Sciences Biomedicine Other Topics	Robotics
Marine & Freshwater Biology	Science & Technology Other Topics
Mathematical & Computational Biology	Spectroscopy
Medical Ethics	Telecommunications
Medical Informatics	Transportation
Medical Laboratory Technology	**Arts & Humanities**
Microbiology	Architecture
Mycology	Art
Neurosciences & Neurology	Arts & Humanities Other Topics
Nursing	Asian Studies
Nutrition & Dietetics	Classics
Obstetrics & Gynecology	Dance
Oncology	Film, Radio & Television
Ophthalmology	History
Orthopedics	History & Philosophy of Science
Otorhinolaryngology	Literature
Paleontology	Music
Parasitology	Philosophy
Pathology	Religion
Pediatrics	Theater
Pharmacology & Pharmacy	**Social Sciences**
Physiology	Archaeology
Plant Sciences	Area Studies
Psychiatry	Biomedical Social Sciences
Public, Environmental & Occupational Health	Business & Economics
Radiology, Nuclear Medicine & Medical Imaging	Communication
Rehabilitation	Criminology & Penology
Reproductive Biology	Cultural Studies
Research & Experimental Medicine	Demography
Respiratory System	Education & Educational Research
Rheumatology	Ethnic Studies
Sport Sciences	Family Studies
Substance Abuse	Geography
Surgery	Government & Law
Toxicology	International Relations

Transplantation	Linguistics
Tropical Medicine	Mathematical Methods In Social Sciences
Urology & Nephrology	Psychology
Veterinary Sciences	Public Administration
Virology	Social Issues
Zoology	Social Sciences Other Topics
	Social Work
	Sociology
	Urban Studies
	Women's Studies

We will look at the classifications of the articles which are assigned to it by the Web of Science database (“subject categories”, from the 242 single classifications of the Web of Science ranging from “Acoustics” to “Zoology”).

In a further step we will try to identify projects where “synergistic” collaborations across disciplines took place. This requires a qualitative assessment that can only be done in the case studies, starting with projects mentioned in the FET-paper on interdisciplinarity. For synergistic collaborations there are some indications mentioned in the FET-paper on interdisciplinarity like: long-term stays, diversity in teams, right to fail-culture, ongoing mutual learning.

Hints for analyzing the results

Interdisciplinary and especially transdisciplinary research as defined in the above section may also be used as a proxy for novelty. For this argument, a series of literature sources exists. An open question however is whether participation of more disciplines automatically results in a higher degree of novelty or “disruptiveness”.

Novelty and interdisciplinarity might be conflicting goals: A high number of project participants may be an indicator for interdisciplinarity but it may at the same time contradict novelty. Many partners in a project may also indicate familiarity with each other because they know each other, regularly meet at conferences and having worked with each other in the past.

Also, in a more general sense it may be asked whether computer science is a separate discipline anymore as we notice that computer science has become an integral part in almost any scientific field.

An interesting aspect in the analysis will be to see whether projects with a high level of interdisciplinarity also have a higher impact in the sense of higher citation rates.

3.2 Innovation eco-systems

What is an innovation eco-system? Usually the term is used for firms, where an *innovation ecosystem* is "the collaborative arrangements through which firms combine their individual offerings into a coherent, customer-facing solution" (Adner, 2006). Enabled by information technologies that make coordination easy, innovation ecosystems become a core element in the strategies of firms in a wide range of industries.

In our case we use the term "eco-system" in a different way. An innovation ecosystem is based on the complex and dynamic relationships that are formed between actors and institutions that enable technology development and innovation. Actors include the material resources such as funding, equipment and the immaterial resources such as knowledge, concepts, tools and experience of the individuals involved to build up this ecosystem. The innovation ecosystems can include institutions such as universities, research institutes, industry, funding agencies business assistance organizations and policy makers.

3.2.1 Relevance I: publications coming out of a FET project

To analyse the spreading of FET ideas within the scientific and industrial R&D community the number of publications coming out of a FET project will be analysed. This analysis is based on the bibliometrics.

We will assign publications from the Web of Science-database and from the CORDIS database to the individual FET projects. We will primarily consider publications that are represented in the Web of Science and exclude publications such as reports and publications without DOI or similar classifications. By this we will determine the number of publications originating from the set of relevant FET projects. It might become necessary to complement the list by some manual analysis.

Another way of counting the number of publications is to look at the publication list of the FET projects which are available on the websites of the projects. Currently this is not possible for all of the projects in our sample because some websites are not online anymore. This will also produce a bias. In the analysis it will be considered to normalize the publication output to the number of project partners and the overall budget of the project.

Another open question is how to proceed with conference proceedings as opposed to journal articles. In some disciplines, namely the computer sciences, proceedings play an important role. We will analyse the importance of proceedings as a publication output to integrate all relevant publications. Proceedings represent a timely communication of research results, they report of preliminary results, small improvements and their status is transitory. Although they are generally less cited than journal articles, proceedings might are important and relevant in the areas of FET projects and technosciences (cf. Lacey, 2012) in general.

3.2.2 Relevance II: Publications with industrial partners

To analyse the dissemination of FET ideas into the industrial realm we will analyse the number of publications related to FET projects with at least one author from industry being part of the project consortium. The methods to be used are bibliometrics and the survey.

3.2.3 Community building I: Transfer of new ideas into the scientific and industrial R&D community - number of citations of FET-project related publications

Another indicator to analyse the FET innovation ecosystem is the dissemination of ideas based on FET projects within the scientific and industrial R&D community. We will analyse the community building through the number of citations of FET-project related publications. For this indicator we will use bibliometric analysis.

3.2.4 Community building II: Dissemination of a new ideas and the genesis of new scientific communities – number of FET-related publications co-authored by researchers who were not involved in the original FET project

Another indicator for community building is the number of publications related to a FET project that are co-authored by researchers from academic institutions that were not involved in the FET project. This is indicating the dissemination of a new idea and the genesis of new scientific communities. The methods to be used are bibliometrics and the survey.

3.2.5 Dissemination of FET ideas into industry: Number of publications that are co-authored by researchers from industrial R&D not involved in the original FET project

To measure the spread of FET ideas into the industrial realm and the community building we will analyse the number of publications related to a FET project that are co-authored by researchers from industrial R&D who were not involved in the original FET project. This phenomenon indicates the spreading of a new idea and the genesis of new innovation eco system. As methods we will use bibliometrics (co-author-analysis) and the survey.

First tests have shown the feasibility and the limits of this co-author-analysis.[6] It might not be feasible for all projects and publications but only for selected ones.

The number of involved researchers in a FET project is in some cases high as FET projects involve up to 26 partner organizations. Bibliometric analyses of co-publications may become very complex. Relevant follow-up articles need to be selected and to be checked whether or not new researchers, not belonging to the original consortium, were involved. Different combinations of the CODIS/ EUPRO data and the Web of Science databases and the survey will be used for co-publication analysis. This indicator is so far highly experimental.

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[6] A first data set of FET related publications in the Web of Science (Grant Number of the project + different notations uses by authors to specify the funding organization [European Union OR European Commission OR EC OR EU OR FP6 OR FP7 OR FET OR Future and Emerging Technologies] identified 3,298 results/ publications [June/August 2016]. About 30 companies were involved in more than 1 publication.

3.2.6 Economic relevance of FET project results: Patent applications which relate to concepts developed in FET projects

To analyse the economic relevance of FET project results, we will identify patent applications which relate to concepts developed in FET projects. The number of patent applications which relate to concepts developed in FET projects indicates that FET project results are starting points for economically relevant activities. Information about patent applications will be obtained through the survey.

3.2.7 Project families analysis: FET projects which triggered other research proposals

The number of FET projects which triggered other research proposals or projects (framework proposals / projects or proposals / projects from other funders in Europe or on the national level) is an indicator for the follow up research activities of FET projects. For this indicator we will use project family analysis, bibliometrics and the survey. Depending on the data from the portfolio analysis it will be decided if this analysis is useful for all FET projects or if it is useful to select a set of projects for a more comprehensive analysis.

3.2.8 Communicating FET results to industry: Number of contributions to proceedings of conferences with industry involvement

One indicator for communicating FET results to industry is the number of contributions to proceedings of (or special sessions at) conferences with industry involvement. This indicates industry interest in FET results and relevance of FET results in industry. The method to be used is the survey.

In principle, it may be possible to identify related articles to conferences with industry involvement is bibliometrics. The challenge however is to distinguish conferences with mere academic participation from conferences with a significant part of industry participation. We will investigate into possibilities to use bibliometrics for this indicator. Possibly a selection of projects has to be carried out.

3.2.9 Industrial relevance: Contacts from industry and cooperation with companies

In the survey we will ask for another aspect of industrial relevance of FET projects – the explicit interest of industrial actors. Questions can be: Were there any contacts from industry, phone calls from company R&D or offers for cooperation by companies?

We may also approach this question indirectly by giving examples or by asking with whom the FET research results were discussed: Were there telephone calls, meetings at conferences or fairs, visits from industry partners, etc.

3.3 Becoming a significant player in the funding landscape

The whole dimension of "becoming a relevant player" might be analysed as the result of the impact assessment using the other three impact dimensions. Another option of describing the image of the FET programme in the public or the research communities is to analyse the presence in media and social media. We assume that FET Flagships are more present than projects from FET Open or FET Proactive or the whole programme itself. There are indicators assigned to this last dimension, however the analysis of this dimension has to be more explorative – taking into account the results of the other dimensions.

3.3.1 Level of awareness and presence of the FET programme for researchers

We will identify the number of researchers saying "FET" when asked about where apply for funding for a new, high-risk, off-mainstream idea which may lead to a groundbreaking a new technology when successful. This can indicate the level of awareness and presence of the programme for researchers. The method to be used is the control group survey.

It was discussed to assign this indicator to the "Innovation eco-system" impact dimension because the indicator is about the ability of the FET programme to attract excellent and creative researchers. As such it is not (only) an indicator for the positioning of FET within the European research funding landscape. In general we have to be flexible how to proceed with this fourth impact dimension. "Becoming a relevant player" is not an impact dimension in a narrow sense. However, asking a control group about the image of the FET programme in the community is interesting indeed from a research point of view.

What the “Becoming a relevant player”-dimension implies – and which has not yet been thought of – is the question of impacting research agendas. One research question thus may be added asking about the impacts of the FET programme or of single FET projects on policy and the research agendas in other contexts, including the national research contexts.

3.3.3 Number of non-FET researchers saying that interdisciplinary, technology-oriented research projects support their academic career

We assume that one indicator for the relevance a funding programme is that the respective project supports the academic career of the participants. As FET-participants might be biased in favour of interdisciplinarity and technology-oriented research, we ask this question to the control group which has not been involved in a FET project sofar.

It can be expected that the control group would only turn to FET when they want to do international collaborative research. However, most national programmes support the principal investigator model so it might be difficult to get valid results from the control group.

3.3.2 Number of FET-participants saying that interdisciplinary, technology-oriented research projects support their academic career

The same question will be asked FET-participants in order to learn about their assessment of interdisciplinarity and technology-orientation on their career. The method to be used is the survey of coordinators and participants of FET projects.

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Annex: Indicators to be covered by the different methodological approaches (internal division of activities)

Methods	Indicators
LDA-analysis (lead: ISI)	New topics: Percentage of FET projects dealing with topics that were not present in the scientific literature before
Portfolio-analysis (lead: AIT)	Input interdisciplinarity: Number of FET projects with project partners from various disciplines (Portfolio-analysis and bibliometrics using the first overview journal article with highest citation to determine input interdisciplinarity)
	Relevance I: Publications coming out of a FET project (Eupro-bibliometrics documented in the portfolio-analysis)
Bibliometrics (lead: ISI)	Relevance I: Publications coming out of a FET project (documented in the portfolio-analysis)
	High impact scientific publications: Number of publications in nature and science (bibliometrics)
	Relevance II: Publications with industrial partners (survey and bibliometrics)
	Output interdisciplinarity: Number of projects with publications in different subject areas in the Web of Science
	Community building I: Transfer of new ideas into the scientific and industrial R&D community - number of citations of FET-project related publications.
	Community building II: Dissemination of a new ideas and the genesis of new scientific communities (see also survey)
	Dissemination of FET ideas into industry: number of publications that are co-authored by researchers from industrial R&D not involved in the original FET project (see survey, not available via bibliometrics)
	Communicating FET results to industry: Number of contributions to proceedings of conferences with industry involvement (not available via bibliometrics)

Project families (lead: AIT)	Project families analysis: Number of FET projects which triggered other research proposals (survey, not available via Eupro bibliometrics) 327
Online-survey asking FET project coordinators (lead: ISI)	Off-mainstream research ideas: Number of FET projects that were rejected before by other funding institutions 3012
	Outstanding excellence: Major scientific awards received for FET-related research 3014
	Novel combination of approaches: Novel composition of the interdisciplinary consortia 3015
	New research avenues for established researchers: Number of researchers pursuing new research directions 3016
	Novelty of outcome: Answers of researchers about the novelty of their results (see also LDA-analysis) 3017
	Economic relevance of FET project results: patent applications which relate to concepts developed in FET projects 326
	Community building II: Dissemination of a new ideas and the genesis of new scientific communities (see also bibliometrics) 324
	Dissemination of FET ideas into industry: number of publications that are co-authored by researchers from industrial R&D not involved in the original FET project (not available via bibliometrics) 325
	Communicating FET results to industry: Number of contributions to proceedings of conferences with industry involvement (not available via bibliometrics)

	328
	Industrial relevance: contacts from industry & cooperation with companies 329
	Number of researchers expecting career impact of FET projects (FET-participants) 332
	Level of awareness and presence of the FET programme for researchers 331 Social impacts
Online-survey control group asking FET-like project coordinators on national levels (lead: ISI)	Percentage of non-FET participants expecting a high impact of interdisciplinary, technology-oriented (FET-) projects for their career 333
	Spin-offs from FET-projects Social impacts