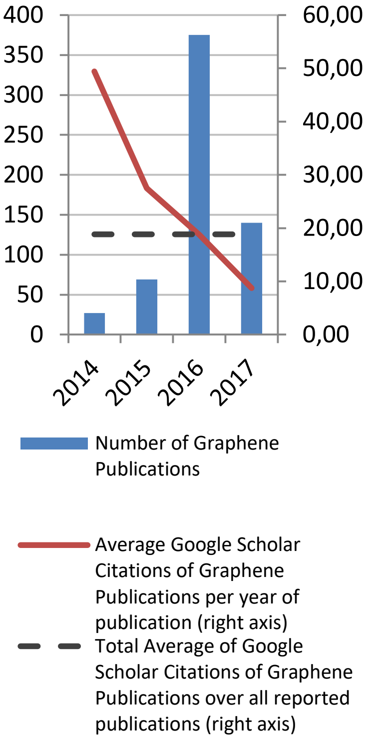
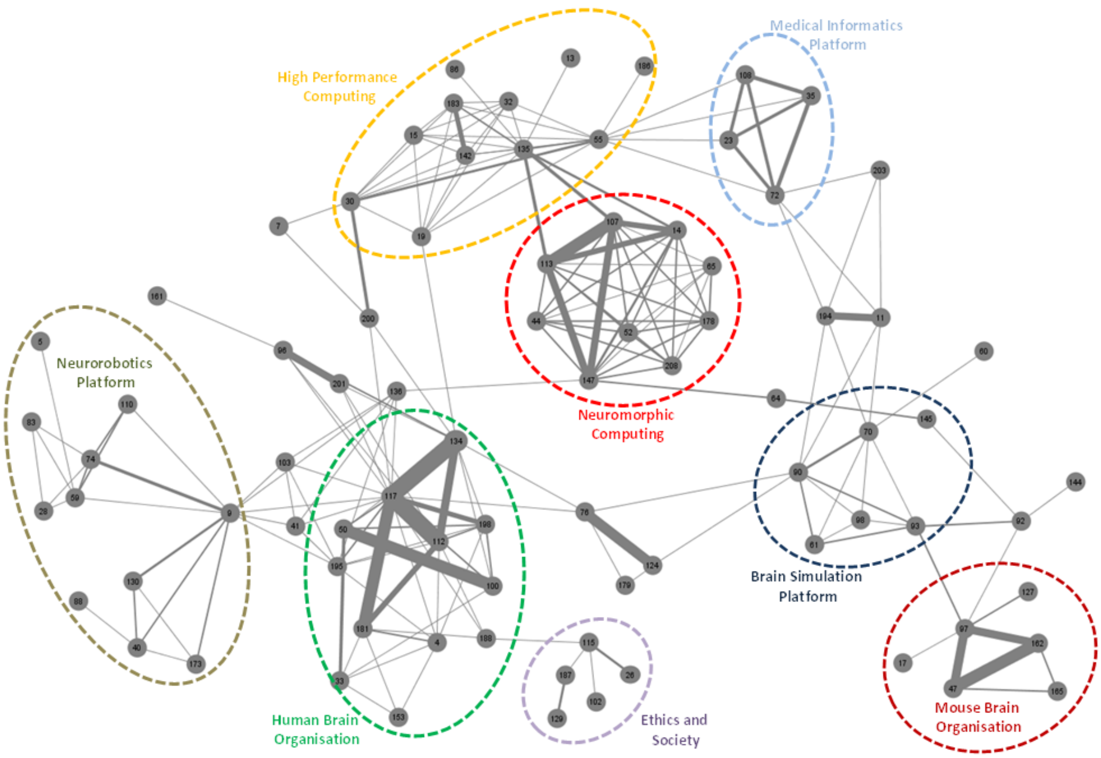
***T**ools and **A**ctions for **I**mpact Assessment and **P**olicy makers **I**nformation*

MEASURING THE IMPACT OF THE EU FLAGSHIPS HUMAN BRAIN PROJECT AND GRAPHENE





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1 INTRODUCTION

In this report we show first impacts of the EU Flagships Human Brain Project (HBP) and Graphene. We underline that we can provide here only first glimpses of impacts, as these can only be measured over a longer time period, and many will occur only after a project has ended.

Flagships are long-term, very large scale research initiatives aiming to solve an ambitious challenge such as understanding the human brain or exploiting the potential of graphene, the newly discovered revolutionary material.

In October 2013 the first two EU Flagships, the Human Brain Project (HBP)[1] and Graphene[2] started operation. While HBP focuses on accelerating the fields of neuroscience, computing and brain-related medicine, Graphene is tasked with bringing together academic and industrial researchers to take graphene material from the academic laboratories into European society.

The Flagships are very different: HBP is more basic research oriented and tending towards a research infrastructure, while Graphene is more in applied research and technology development. Because of these differences it is not useful to make direct comparisons between them, but rather pick out elements to illustrate preliminary impacts of both projects.

These long-term initiatives are planned for a run-time of about 10 years. They started with a 2.5 year ramp-up phase, which lasted until March 2016. In March 2018 they finished their second phase of the Specific Grant Agreement 1 (SGA1).

The TAIPI project[3] supported the EU Flagships with impact measurement and evaluation from January 2015 until April 2018. TAIPI was a coordination and support action funded under the EU's Horizon 2020 programme. TAIPI's main task was to set up a measurement system for impacts and test the system in practice.

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[1] https://www.humanbrainproject.eu/
[2] http://graphene-flagship.eu/
[3] https://taipi.eu/

The TAIPI project was coordinated by ERDYN Consultants (France), and partners were Centre for Social Innovation (ZSI, Austria), Technical Research Institute of Sweden (SP, meanwhile part of Research Institutes of Sweden - RISE; Sweden), Swiss Federal Institute of Technology Lausanne (EPFL, Switzerland), and The French National Research Agency (ANR, France)

A methodological framework for impact measurement was defined by the TAIPI consortium. As illustrated in the figure below, we classified the expected impacts of the Flagships into six categories (structural, etc.). On this basis we specified single indicators per each impact dimension.

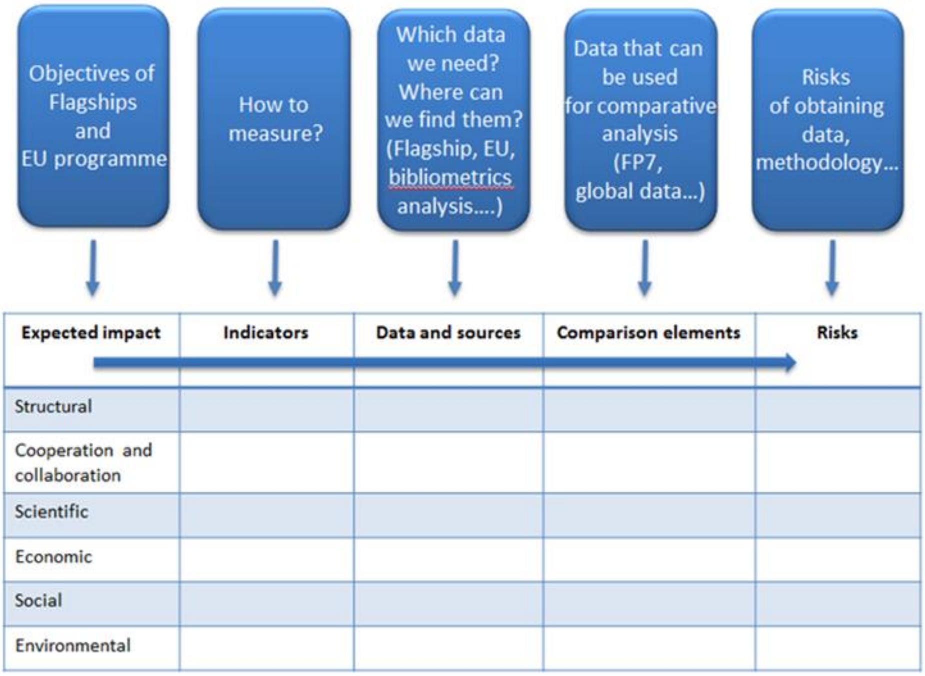

Figure 1: TAIPI logical framework for Flagship impact assessment

In the following we explain the dimensions briefly, and give then examples of indicators for each impact dimension, except for environmental dimension. For this dimension we had no data yet at time of preparing this document.[4]

[4] We would like to note as well, that we had data available for both Flagships for the ramp-up phase (2013-2016), but for the Specific Grant Agreement Phase 1 (SGA1) we had only data for HBP.

Structural impact

Structural impact refers to the set-up of the Flagships, including its partnership and scientific disciplines represented. The objective is to analyse the functioning of the Flagships and their role in the emergence of an organised scientific community. Indicators include for example number and type of partners involved.

Cooperation & collaboration

This impact dimension refers to cooperation in the Flagships and beyond, as well as to intensity of collaboration. Intra-European and international cooperation as well as networks created within the Flagships are considered. Indicators measure co-publication patterns and development of cooperation networks.

Scientific impact

Scientific impact is the most evident to analyse. Excellence of research will be measured for example in numbers of publications, citations, and in number and type of prizes and awards.

Economic impact

Economic impact relates to involvement and cooperation with business, knowledge transfer and intellectual property rights. Measurable data will include partnerships and contracts with industry, spin-off creation and survival rates, and patent analysis.

Social impact

Social impact covers many dimensions, including progress for health, acceptability of new products, education by research, policy diffusion and responsible research and innovation (RRI).

Environmental impact

Environmental impact is relevant mostly for the Graphene Flagship, and indicators include new materials and solutions developed for environmental applications.

2 STRUCTURAL IMPACTS

2. 1 The Flagships are Europe-wide excellence projects

i. Geographic leadership

The leadership positions in the Flagship and where these leaders are located, give an indication from which countries the Flagship are driven. In the map below (Figure 2) we show the number of Principal Investigators (leading a task) in the HBP per country in the SGA1 phase (April 2016 – March 2018). We relate this to the research capacity of the country measured in terms of available Full Time Equivalents (FTEs) of research personnel. In absolute terms, most PIs in HBP are based in Germany, then in Switzerland, France, UK, Spain and Italy and these are therefore the driving institutions and countries in the project. Related to research capacity, it is Switzerland, Norway, Hungary and Slovenia, which have the strongest involvement in terms of PIs in the HBP. The strong showing of Switzerland is related to the fact that HBP is coordinated by the EPFL Lausanne.

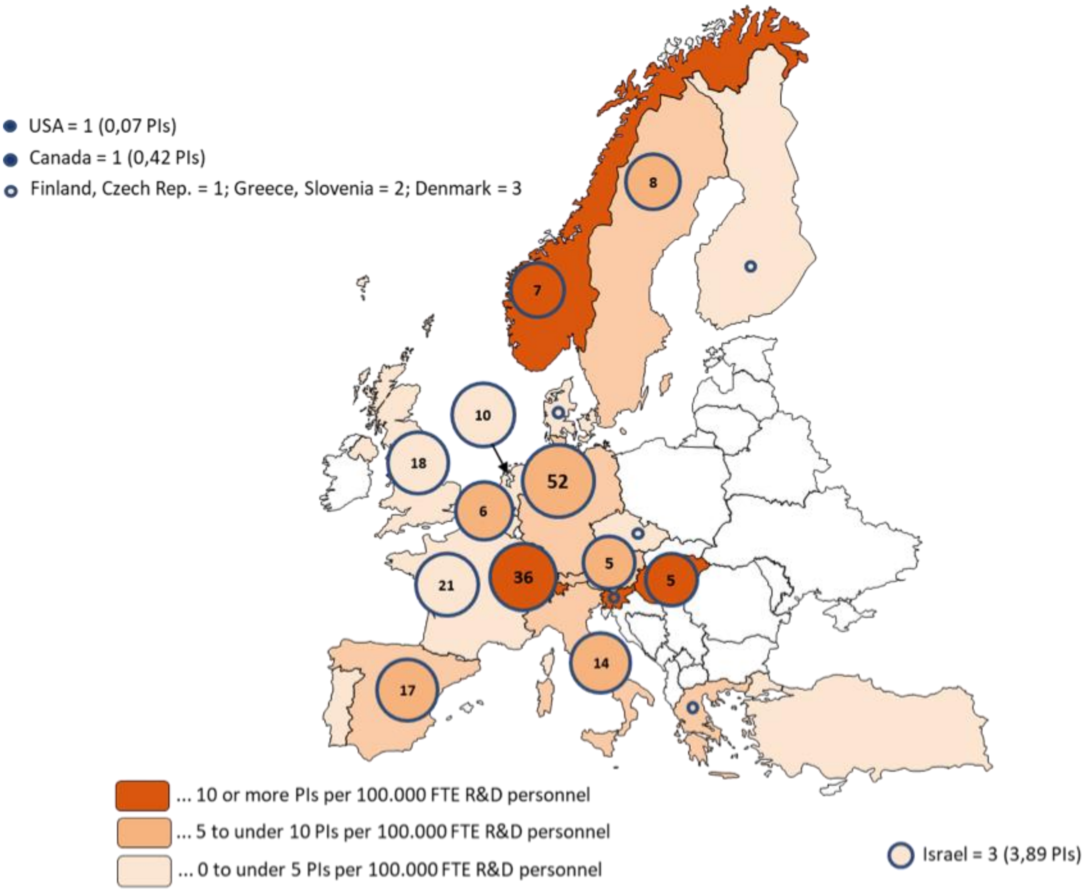

Figure 2: Number of Principal Investigators (PIs) involved in HBP per country (for SGA1), and related to research capacity of country (n=213)

ii. University involvement

We analyse here the involvement of universities in the Human Brain Project, and their placement in international university rankings. We use the Times Higher Education (THE) ranking of European universities.[5] Among the HBP core partnership in the SGA1 phase we have 83 European universities. From this sample 58 are placed in the Times Higher Education (THE) ranking of European universities up to rank 200. This makes a share of 70% of HBP universities in this ranking band.

Among the top 20 of European universities according to THE, there are 14 which are participating in HBP. This is a high share. While the methodology and use of these rankings are under discussion, they still give an indication of the quality of universities. The comparison of HBP universities between ramp-up and SGA1 phase reveals an increase from 49 to 58 universities placed in the (THE) ranking up to place 200.

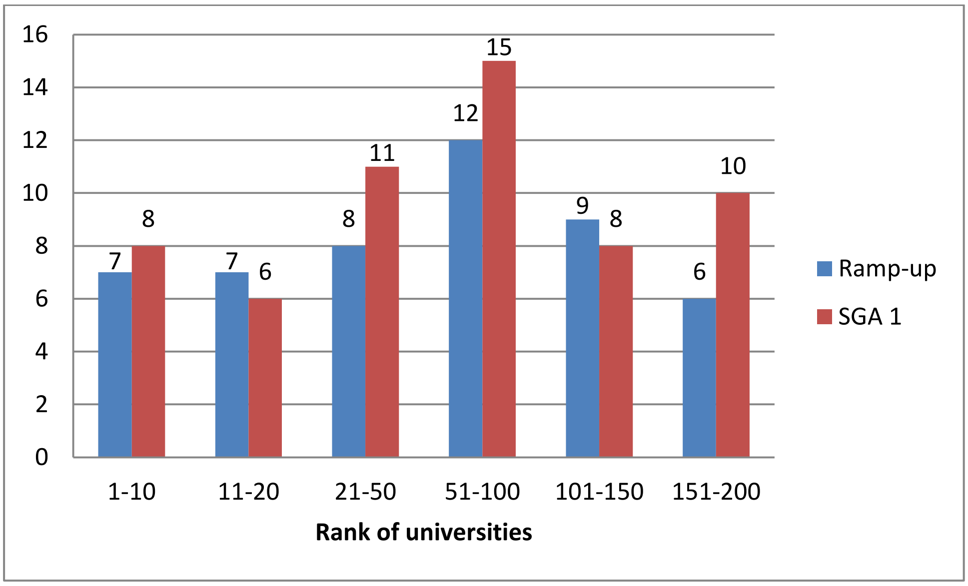

Figure 3: Number of universities involved in HBP, according to their rank in THE Top 200 European Universities (n=58 for SGA1, n=49 for ramp-up phase)

The ranking reveals that for many countries **it is the top ranked universities among European universities, which are involved in the core membership of HBP**. For example:

- the overall top ranked university, Oxford University is involved in HBP core members, as well as,

[5] https://www.timeshighereducation.com/student/best-universities/best-universities-europe

- the two best ranked Belgian universities (KU Leuven – rank 14, Ghent university – rank 42),
- the two best ranked Italian Universities (Scuola Superiore Sant'Anna – rank 74, Scuola Normale Superiore di Pisa – rank 92),
- the two best ranked Swiss Universities (ETH Zurich – rank 4, EPFL Lausanne – rank 10),
- the two best ranked Swedish Universities (Karolinska Institute – rank 10, Uppsala University– rank 29)
- the best ranked Dutch (University Amsterdam – rank 16), Norwegian (University Oslo – rank 67), and Spanish universities (University Pompeu Fabra – rank 62).

3 COOPERATION & COLLABORATION

3.1 The Flagships are attractive for international cooperation

The Human Brain Project managed to attract and educate PhD students originating from 41 different countries. It is obviously attractive for a high number of international PhD students. A significant share of overall 27% of PhD students in HBP are stemming from non-EU member countries. If we distinguish it further, we can note 9% coming from countries associated to Horizon 2020[6] and 17% from so called third countries (non-EU, non-associated). More than 70% of PhD students have an EU nationality.

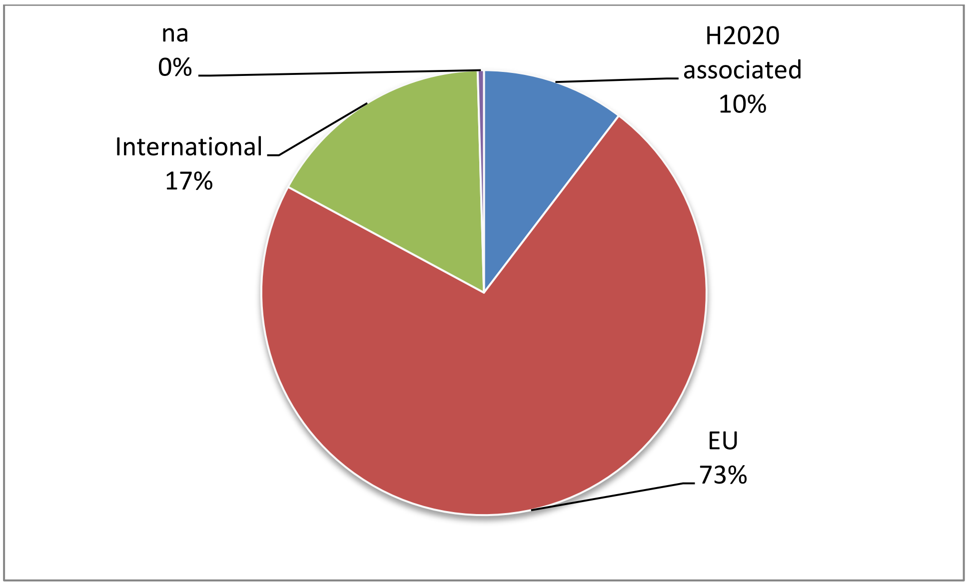

Figure 4: Percentage of HBP PhD students by region of origin (n=222)

[6] Countries associated to the EU's Horizon 2020 programme are: Albania, Bosnia and Herzegovina, Faroe Islands, FYROM - the former Yugoslav Republic of Macedonia, Georgia, Iceland, Israel, Moldova, Montenegro, Norway, Serbia, Switzerland, Tunisia, Turkey, Ukraine

3.2 The Flagships generate strong research networks

We take as indicator co-publications among Principal Investigators (PIs) involved in the Human Brain Project to show the research networks generated and their interdisciplinarity. In order to visualise the co-publication network between the PIs we use the network analysis program Visone[7] which computes and visualises social interaction (i.e. the number of co-publications between PIs) in a 2-dimensional "map".

The title page of this document features the clusters of co-publication networks formed in the frame of HBP ramp-up and SGA1 phase. We zoom in into one of the strongest specific networks, the clusters around research centre Jülich and university Heidelberg, both from Germany.

Figure 5 illustrates the 3 sub-clusters Neuromorphic Computing (orange colour), High-Performance Computing (red colour) and Medical Informatics Platform (blue colour). We discuss the cluster "High-Performance Computing", which is thematically more heterogeneous including PIs from four different Sub-Projects (SP) of HBP. This variety points to interdisciplinary research cooperation and publications. SP7 (High-Performance Computing) is clearly leading, followed by SP9 (Neuromorphic Computing). Its institutional heterogeneity is also much more pronounced having PIs from different institutions and countries. Research Centre Jülich (Germany) with 3 PIs is in the lead (the University of Manchester follows with 2 PIs) and hence we call this sub-cluster as "dominated" by Jülich. Nevertheless, despite this high degree of heterogeneity the interconnectivity of this sub-cluster is still remarkable.

[7] https://visone.info/

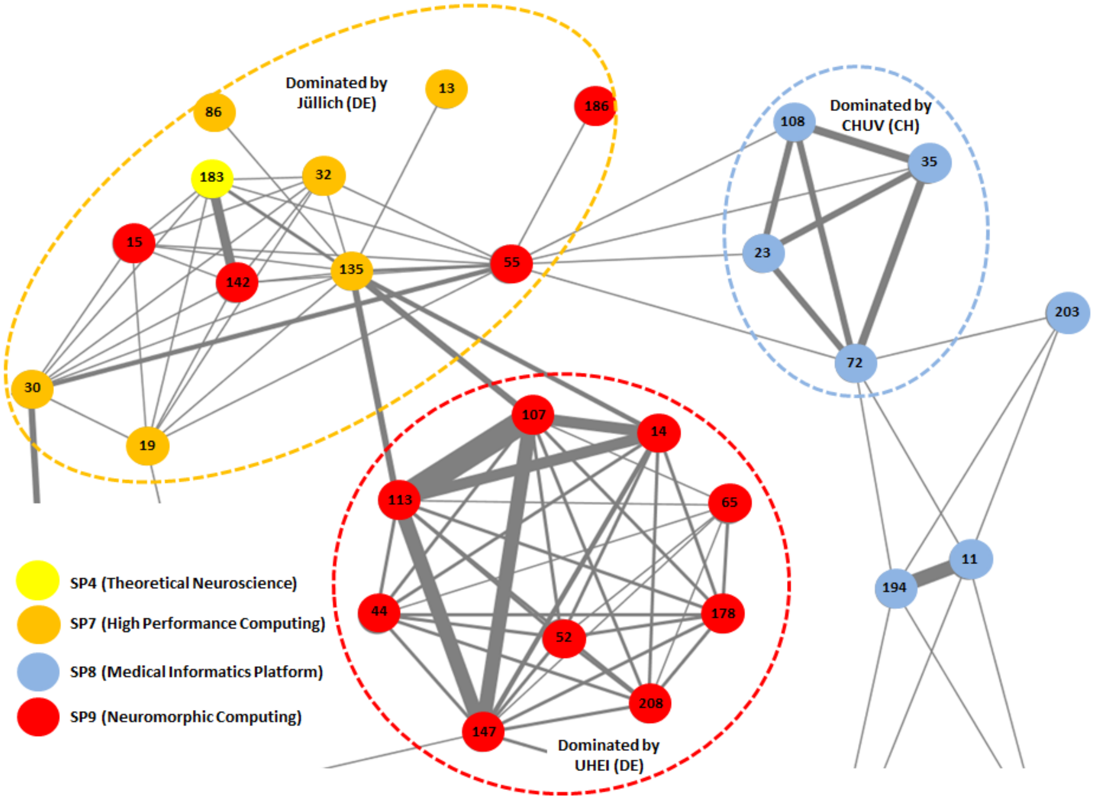

Figure 5: Neuromorphic Computing, High-Performance Computing and Medical Informatics Platform

Note: Only PIs who are linked into the overall co-publications network are represented in this figure. Also, additional authors who are not PIs in HBP were not taken into account; the thickness of the lines denotes the weight of the linkage (i.e. number of co-published papers) between PIs. The numbers within the circles correspond to different PIs. Their respective institutional backgrounds are as follows:

UHEI – Univ. Heidelberg (DE) = 107, 14, 52, 65, 178, 147, 113	**UCL – Univ. College London (UK) = 108**
Jülich Research Centre (DE) = 32, 19, 135, 142, 183	**AUEB – Athens Univ. of Economics and Business (GR) = 11**
CHUV – Univ. Hospital Lausanne (CH) = 23, 35, 72	**ICL – Imperial College London (UK) = 194**
UMAN - Univ. Manchester (UK) = 55, 186	**CNRS (FR) = 15**
RWTH Aachen (DE) = 30	**TU Graz (AT) = 208**
NMBU - Norwegian University of Life Sciences (NO) = 86	**TUD - TU Dresden (DE) = 44**
BUW - Univ. Wuppertal (DE) = 13	

4 SCIENTIFIC IMPACT

4.1 Flagships produce significant publication output in leading scientific journals

The number of publications in the Graphene Flagship during the first year of the SGA1 phase (1 April 2016 – 31 March 2017) reached a significant number of 611 publications (Figure 6 lists all publications attributed to this one year period).

At the same time the attention for this publication output has been significant as well. This is indicated by the number of average google scholar citations each Graphene publication received. The total average of google scholar citations received by Graphene papers has in April 2018[8] been about 19 citations per Graphene paper. However, Graphene papers which have been published as early as 2014 have an average number of google scholar citations of almost 50 per paper, significantly above the average google scholar citations of the total of Graphene papers of the SGA 1 phase. This is a clear indication that the impact of the published scientific Graphene output within their respective scientific community will increase further in the years to come.

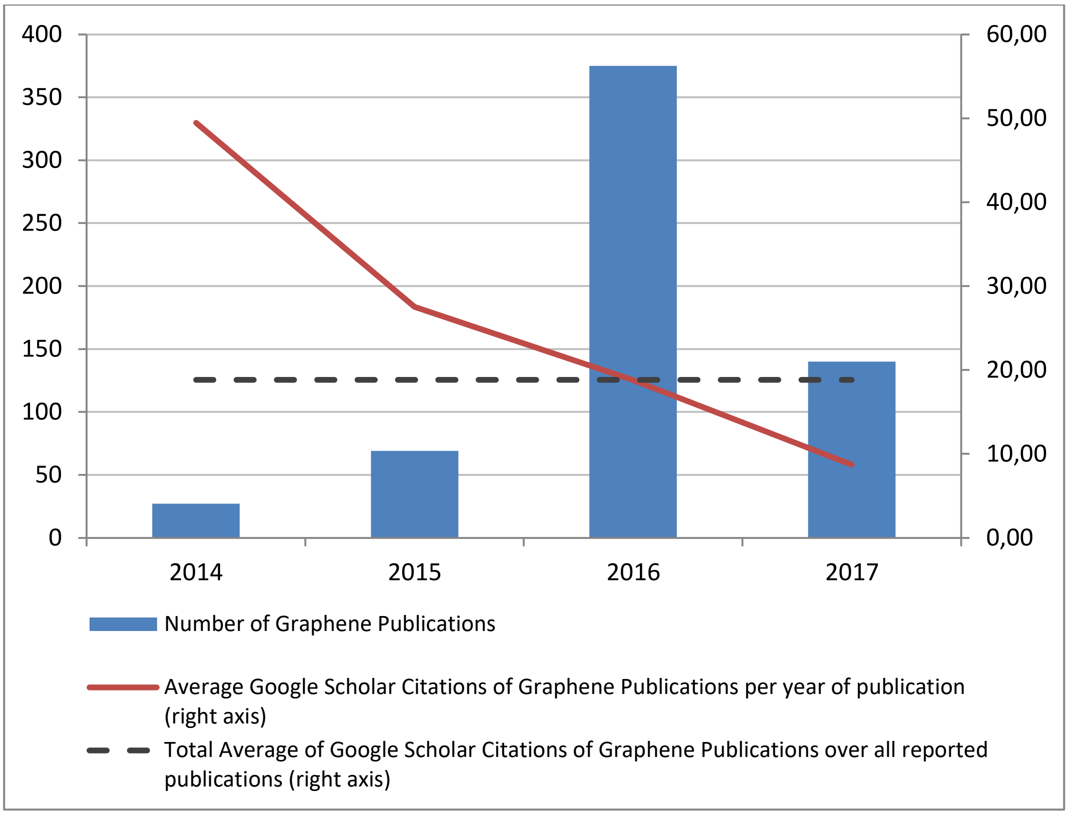

Figure 6: Graphene publications for the first year of SGA 1 (1 Apr 2016 – 31 Mar 2017): Basic Indicators
Source: Own calculation based on Publication Data provided by Graphene Flagship Management

[8] Google Scholar Citation Numbers for all GRAPHENE publications were retrieved in the first week of April 2018.

Table 1 gives the list of the 15 journals most commonly used for publication of Graphene Flagship papers. These journals account for more than 50 % of the total Graphene Flagship publication output alone. The most important journal (with respect to the absolute number) is “Physical Review B - Condensed Matter & Materials Physics“ which received 64 Graphene Flagship papers (or about 10 %), whereas the second most important journal (“2D Materials”) received with 41 papers (or about 7 %) “only” about two third as much publications.

Some of these most used journals are highly specialised (e.g. 2D Materials, Nano Letters, ACS Nano), while only a handful are “general” journals (i.e. Nature Communications, Nature, Applied Physics Letters) covering a wider range of thematic areas.

Journal	Number of Publications in Journal	Share of all Publications	Share of all Publications Cumulative
Physical Review B - Condensed Matter & Materials Physics	64	10.5	10.5
2D Materials	41	6.7	17.2
Nano Letters	37	6.1	23.2
Nature Communications	26	4.3	27.5
Journal of the American Chemical Society	20	3.3	30.8
Advanced Materials	19	3.1	33.9
ACS Nano	17	2.8	36.7
Carbon	16	2.6	39.3
Applied Physics Letters	15	2.5	41.7
Scientific Reports	15	2.5	44.2
ACS Photonics	12	2.0	46.2
Angewandte Chemie - International Edition	10	1.6	47.8
Nanoscale	10	1.6	49.4
Physical Review Letters	10	1.6	51.1
Nature	9	1.5	52.5

Table 1: List of the 15 most important journals for GRAPHENE publications

4.2 Flagship researchers give sizeable numbers of invited talks at conferences

The Graphene Flagship management team has reported for the ramp-up phase 465 invited talks (not exclusively at conferences). In addition over 1,142 dissemination actions were registered. From the list of dissemination actions, 226 are labelled as invited. These talks were mainly performed in the European Union. In a smaller number, Graphene Flagship researchers were invited to North America and Asia. In Europe, most of the talks were given in France, United Kingdom, Germany, Spain, Italy, and Switzerland.

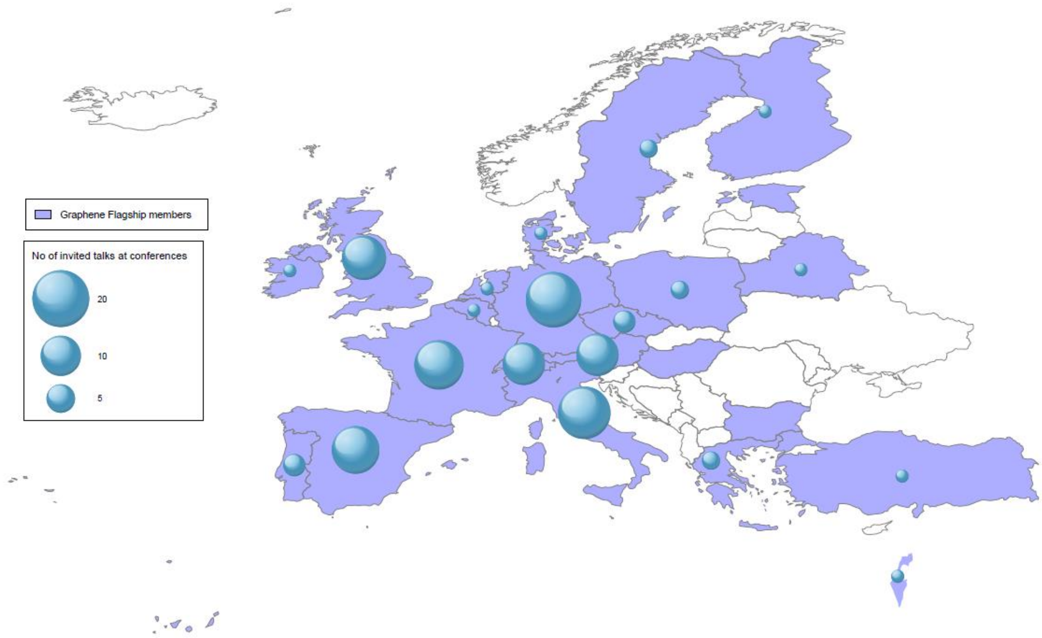

Figure 7: Number and location of invited talks in Europe in the presence of a scientific audience (data for Graphene, Oct. 2013-Mar.2016)

4.3 HBP Flagship is an important ICT and infrastructure related project

Under this indicator we give an insight into thematic fields involved in the HBP Flagship. An analysis of the scientific fields of PhD students confirms that HBP is an important ICT related project. We have used the OECD Frascati Manual classification[9] of scientific fields for categorising the PhD students. The field Computer and information sciences comes far ahead as strongest with 90 PhD students, followed by biological sciences with 41 PhD students.

[9] OECD: www.oecd.org/sti/inno/frascati-manual.htm

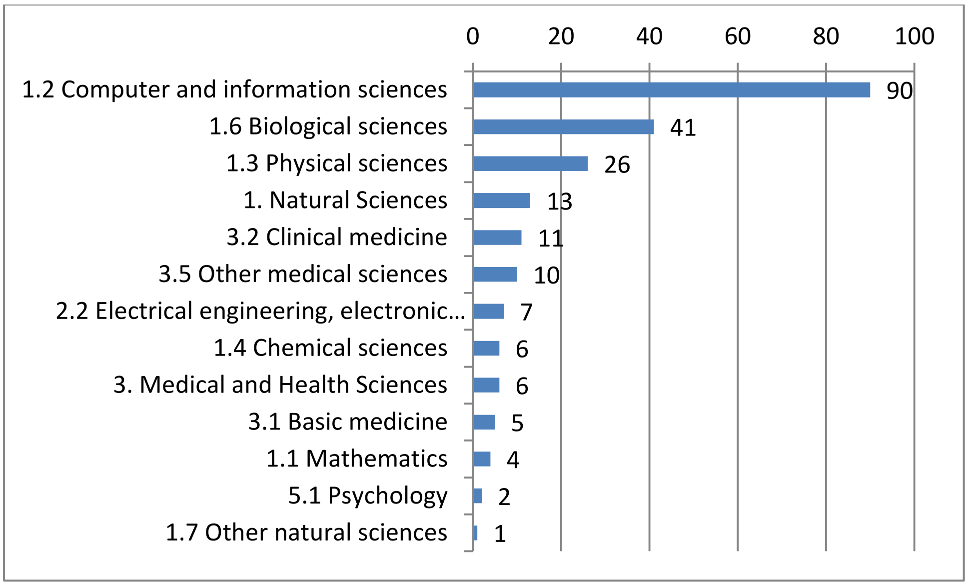

Figure 8: HBP PhD students by scientific fields (n=222)

We have summarised the scientific fields into two broad categories: health/medicine and information and communication technologies (ICT) related. While this rough classification is not exact, it confirms again the strong ICT component of the HBP Flagship. About 64% of PhD students follow studies in ICT topics or closely related topics. PhD students in Health /Medicine and related fields make up 36% of PhD students. The basis for this strong ICT component are information technology platforms set-up by HBP.

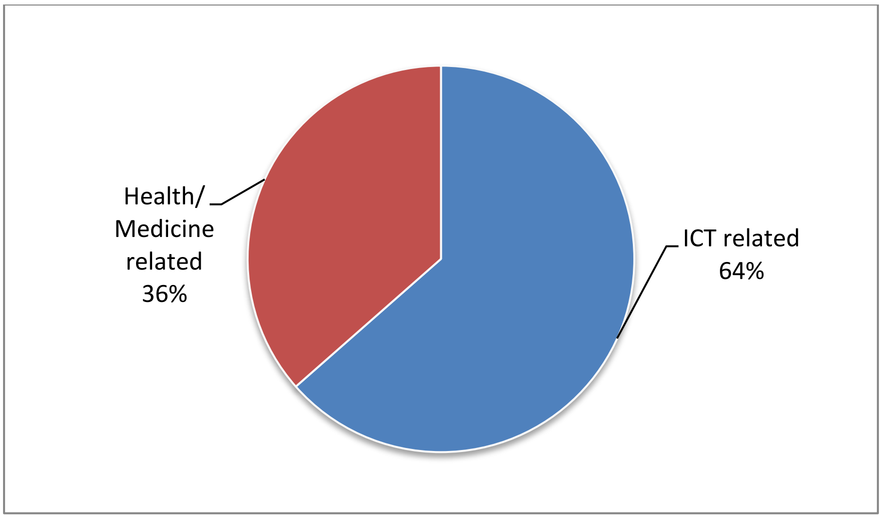

Figure 9: HBP PhD students by ICT versus health/medicine related scientific fields (n=222)

5 ECONOMIC IMPACT

5.1 Knowledge transfer is ensured

i. Company involvement in the Flagship membership

Graphene Flagship has undergone during its implementation several changes and has been expanded significantly. In the ramp-up phase it comprised 138 members, including 17 SMEs, 17 large companies, and the rest of 104 institutions distributed over universities, public research organisations, public authorities, and others (data as in May 2016, Figure). A significant share of about a quarter of members was at that point companies. The strong company involvement ensures joint research and innovation activities among research and business within the Flagship, and a mutual transfer of knowledge. User requirements can be communicated herewith effectively to research players. Companies involved in Graphene include well-known such as Nokia, Ericsson, Alcatel, Aixtron Ltd., Lego, and others.

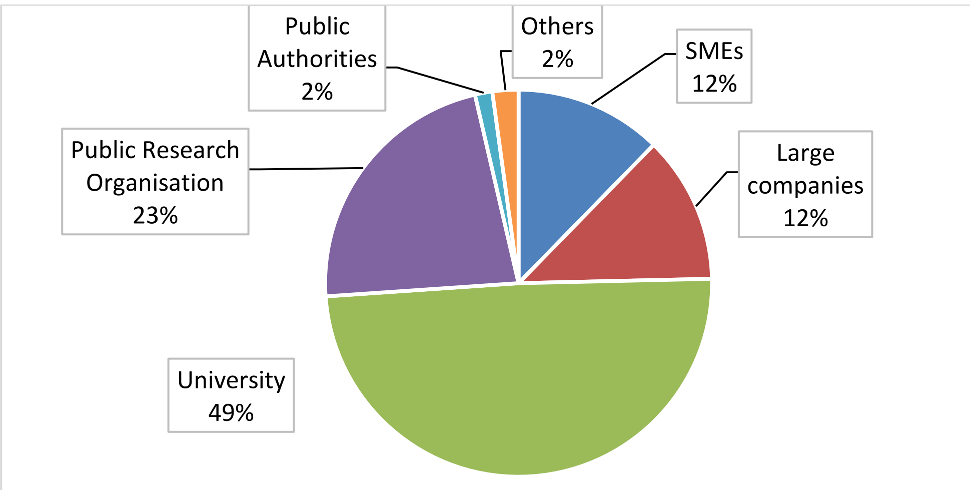

Figure 10: Graphene members per type for ramp-up phase (n=138)

ii. Cooperation with companies beyond the Flagship membership

The Flagships have intense cooperation with companies beyond their membership. Data on informal and formal cooperation confirm this finding. In addition we have conducted qualitative interviews on this issue in the first TAIPI impact evaluation round for the ramp-up phase. These revealed that close cooperation and linkages to companies at the level of individual HBP members, and cooperation with companies has been established thanks to the HBP Flagship. Cooperation was ongoing with well-known multinational companies such as Bosch, Volkswagen, IBM and Samsung. Several local SMEs have been involved in establishing the HBP IT platforms, and companies are expected to make use of the platforms in the future. Young researchers trained are regularly transferring to large companies and to innovative SMEs in electronics, computer, and space industries. The impact of the HBP Flagship on the business sector and the whole economy can even be expected to be revolutionary and game changing, as it is dealing with unconventional computing and artificial intelligence.

6 SOCIAL IMPACT

6.1 The Flagships are important educational projects

i. Education of PhD students

Flagships fulfil the essential task of educating the younger researcher generation. In the HBP the share of PhD students in progress (working on their PhD) increased considerably from 120 to 190 PhDs, if we compare the ramp-up to the SGA1 phase. This is an increase of nearly 60%.

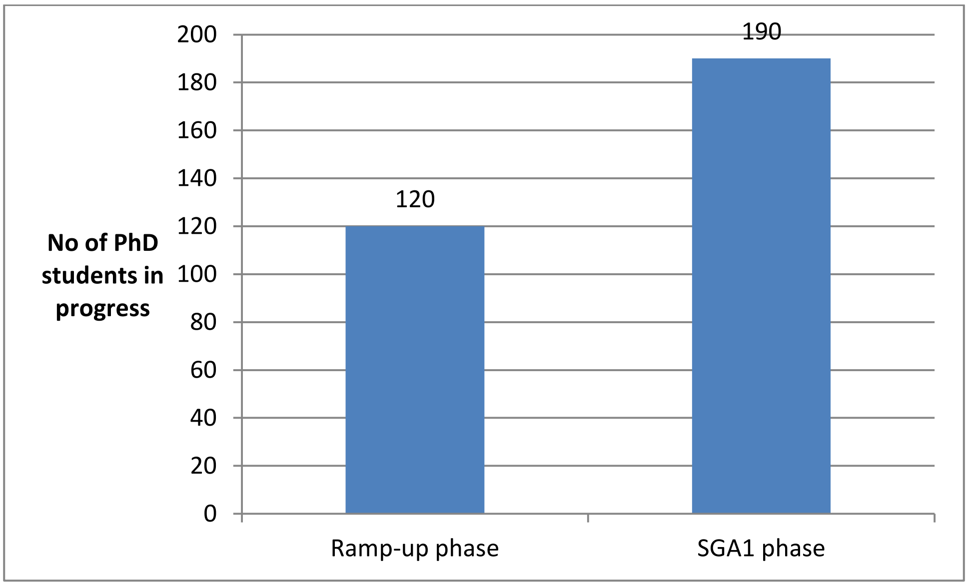

Figure 11: HBP PhD students in progress in ramp-up and SGA1 phase

ii. Training through workshops

The Graphene Flagship organises of workshop series, called "Connect" intended to provide state of the art content to academics and industrials. During the ramp-up phase, the Flagship organised seven such workshops. Each one focused on a specific field of science related to a Graphene Flagship Work Package. Based on the workshop list, two workshops were addressed to industry: **"**Benefit from graphene in your R&D development" held in France and "Investment opportunities" held in the United Kingdom**.**

Title of the Workshop	City	Country
Benefit from graphene in your R&D development	Grenoble	France
Nanocomposites	Toulouse	France
Sensors	Gothenburg	Sweden
Energy applications	Dresden	Germany
Photonics and Electronics	Barcelona	Spain
Materials and production	Bilbao	Spain
Investment opportunities	Manchester	United Kingdom

Table 2: List of Workshop series "Connect" organised by Graphene Flagship during ramp-up phase

6.2 The Flagships reach out and inform the general public

Graphene Flagship has held in the ramp-up phase (October 2013 - March 2016) two exhibitions and reached out to significant numbers of citizens. In June 2014, an exhibition opened at the **Universeum in Gothenburg** (the largest museum of science in Scandinavia), where visitors could find out about graphene. Universeum exhibition was displayed for about one year with an average annual visitor attendance of 576,000. Moreover, the Graphene Flagship introduced a Graphene Zone at the 2016 edition of the **Mobile World Congress** in Barcelona, where the general public was also present. Alongside with industry and academic co-exhibitors, the flagship highlighted graphene in mobile applications, stretching from bendable batteries to new wearables sensors. This congress counted 100,000 visitors.

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