EUROPEAN COMMISSION

DIRECTORATES-GENERAL FOR RESEARCH AND INNOVATION (RTD) AND COMMUNICATIONS NETWORKS, CONTENT AND TECHNOLOGY (CONNECT)

BACKGROUND DOCUMENT

PUBLIC CONSULTATION

'SCIENCE 2.0': SCIENCE IN TRANSITION

0. OVERVIEW OF THE CONSULTATION PROCESS

This background paper to the online public consultation gives a short description of the term 'Science 2.0' as used in this consultation. The goal of the consultation is to better understand the full potential of 'Science 2.0' as well as the desirability of any possible policy action.

The current transition of the science and research system results predominantly from a bottom-up process driven by the increasing number of researchers operating in a globally networked digital system and by the increasing societal demand to address the Grand Challenges of our times. The key-stakeholders (universities, research funders, libraries, researchers, publishers, businesses) find themselves in various stages of responding or adapting to the evolving situation. For example, universities are considering new ways to evaluate researchers' careers and requiring new types of research skills from researchers. The impact of research is of growing importance to research funding organisations. Publishers are active as they are moving towards models of Open Access to publications and research data. New players emerge with regard to determining the impact of research.

In this consultation process, 'Science 2.0' is therefore understood as a systemic change in the modus operandi of doing research and organising science.

The three main objectives of the consultation are:

1. to assess the degree of awareness amongst the stakeholders of the changing modus operandi,
2. to assess the perception of the opportunities and challenges, and
3. to identify possible policy implications and actions to strengthen the competitiveness of the European science and research system by enabling it to take full advantage of the opportunities offered by Science 2.0.

The consultation aims to consult the stakeholders at large on key drivers, barriers, and opportunities that are transforming science and research.

CONSULTATION PROCESS

A broad consultation process is launched for all relevant European stakeholders and interested parties to better understand potential impact of 'Science 2.0' and the desirability of policy action. The outcomes of this consultation will subsequently be validated during multi-stakeholder activities, such as workshops, in the autumn of 2014.

1. Introduction

'Science 2.0' describes the on-going evolution in the modus operandi of doing research and organising science. These changes in the dynamics of science and research are enabled by digital technologies and driven by the globalisation of the scientific community, as well as the increasing societal demand to address the Grand Challenges of our times. They have an impact on the entire research cycle, from the inception of research to its publication, as well as on the way in which this cycle is organised. The institutions involved in science are affected (research organisations, research councils, funding bodies), as is the way in which science is disseminated and assessed e.g. the rise of new scientific disciplines, innovative pathways in publishing (among them a substantial rise of Open Access journals), new scientific reputation systems, and changes in the way the quality and impact of research are evaluated. These trends are irreversible and they have already grown well beyond individual projects.

The impact of these trends is already visible and it addresses some of the most burning issues of science, such as the slowness of the publication process, the increasing criticism of the existing peer review system, and the challenge of reproducing research results due to the lack of available data.

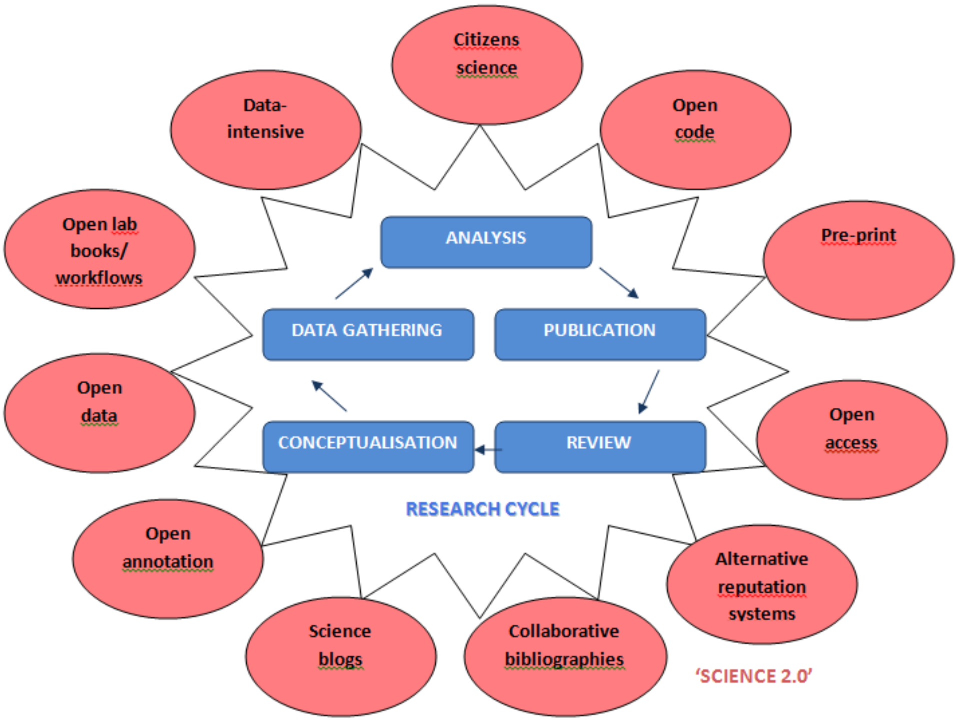
This paper describes the

- components of 'Science 2.0',
- drivers of 'Science 2.0',
- implications of 'Science 2.0' for society and the economy, the research system and for researchers,
- opportunities for and barriers to 'Science 2.0', and
- role of research funding organisations, the Member States and the European Union.

1.1 What is the issue?

The 'opening up of the research process' is visualised in the figure below (see *figure 1*). The outer-circle identifies the interconnected trends within 'Science 2.0' whereas the inner-circle visualises the entire scientific process, from conceptualisation of research ideas to publishing. Each step in the scientific process is linked to on-going changes entailed in 'Science 2.0', such as the emergence of alternative reputation systems, the growing use of scientific blogs, open annotation and access to data and publications (see figure 1). 'Science 2.0' as a *holistic approach*, therefore, is much more than only one of its features (such as Open Access) and represents *a paradigm shift in the modus operandi of research and science* impacting the entire scientific process.

Figure 1:*'Science 2.0': Opening up the research process*



'Science 2.0' encompasses:

1. A significant increase of *scientific production*: This includes open science, i.e. access to scientific data as well as reliability of scientific discovery (e.g. access to methods, tools, data, and articles). Furthermore, one can observe a changing paradigm towards open research collaboration. Open research collaboration is the large-scale, remote collaboration of scientists with the use of internet-based tools similar to open source software collaboration. Open Access can be defined as the practice of providing on-line access to scientific information that is free of charge to the end-user. In the context of research, 'scientific information' refers to peer-reviewed scientific research articles (published in academic journals), scientific research data (data underlying publications, curated data and/or raw data) and other forms of scientific output (e.g. monographs, conference proceedings, theses, grey literature).

2. A new way of doing science: *data-intensive science*, enabled by the availability of large-scale datasets (at petabyte level) processed through simulation software and enabled by high performance computing. Currently 52 % of scientists use datasets larger than 1 Gigabyte. A full 90% of all the data in the world has been generated over the last two years. Scientific data output increases at an annual rate of 30 percent. (Science Daily, 22 May 2013)

3. An *increase in the number of actors in science and addressees of science*: Every decade now produces as many new scientists as have lived before.[1] On the other

[1] G.Schatz (2014), The faces of Big Science, Nature Review, Molecular Cell Biology, Vol.15, p.423, June 2014

hand, the number of actors is growing, for example via *citizen science*, as a form of research collaboration in which citizens, often with a particular interest and/or stake in the outcome of the research, contribute to research. For example, there are currently close to 900,000 people engaging in the 'Zooniverse' citizen science projects[2].

Moreover, citizens and civil society organisations also increasingly manifest themselves as funders and 'agenda setters' for scientific research; for example via patient groups that fund research on specific diseases, via philanthropic foundations like the Bill & Melinda Gates Foundation, or via new (social media) models like 'crowd funding'. This direct, active involvement of citizens and stakeholders in both the steering of science as well as the provision of data and knowledge for advancing research reflects a trend towards the societal embedding of science and the orientation of scientific research agendas towards addressing societal challenges. This is linked to an underlying normative dimension of democratisation of science, in connection with advances in ICT and social innovation. Furthermore, citizen involvement in the scientific endeavour contributes to furthering interactive processes of knowledge utilisation and knowledge valorisation and to making research more relevant to society.

The above described trends include interconnected changes towards a more open science and research process involving, among other, trends towards the use of open data, open code, open annotation, data-intensive science, Open Access, new forms of collaboration etc. The growth and use of social media by researchers which could be coined as 'Facebook for Scientists' is exemplified in Box 1.

2 The Zooniverse and the suite of projects it contains is produced, maintained and developed by the Citizen Science Alliance (CSA). The member institutions of the CSA work with many academic and other partners around the world to produce projects that use the efforts and ability of volunteers to help scientists and researchers deal with the flood of data that confronts them. See https://www.zooniverse.org/

Box 1 Examples of 'Facebook for Scientists': The growing use of social media by researchers

Academia.edu

Academia.edu is a USA based- platform for academics to share research papers. The company's mission is to accelerate the world's research. Academics use Academia.edu to share their research, monitor deep analytics around the impact of their research, and track the research of academics they follow. 8,897,412 academics have signed up to Academia.edu, adding 2,594,654 papers and 1,059,921 research interests. Academia.edu attracts over 15.7 million unique visitors a month.

Academia.edu is backed up by investors with a total of 17.7 million dollars.

Research Gate

Berlin-based, virtually identical functions as Academia.edu, however it generates a ***Research Impact Factor*** for the uploaded documents of researchers, based among other on the classical citations but also on the number of downloads by other users.

4 million users, founded in 2008. Research Gate received in 2012 the German Entrepreneurs Award and Bill Gates invested in 2013 in Research Gate to advance Open Science. 67 million Publications available, 193 countries.

Mendeley

Mendeley is a ***reference manager***. Apart from the 'Facebook for Scientists" features, Mendeley also allows for open annotation and generation of bibliographies.

About 3 million users and recently bought by Elsevier: Amsterdam based.

Figshare

Figshare is an ***online digital repository*** where researchers can make their research outputs available in a citable, shareable and discoverable manner, including figures, datasets, images, and videos.

Figshare was launched in January 2011 and re-launched in January 2012, following support from Digital Science, a division of Macmillan Publishers. During its first year of operation 200,000 files were made publicly available. In September 2013 about 1 million research objects were available.

2. Drivers of 'Science 2.0'

Main drivers of 'Science 2.0' may include:

- The tremendous increase in the number of researchers. This implies a huge need for platforms that are used as part of a scientific career to publish,[3] to collaborate, etc.
- The new emerging scientific powerhouses (e.g. Asia): The number of scientific institutions is growing rapidly both in Europe and in the rest of the world, particularly in China which will soon possess the biggest research population worldwide. Additionally, the number of students is increasing enormously.[4]

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[3] By way of illustration, ± 11.000 articles are submitted annually for publication in *Nature*, of which 800 are published; the acceptance rate of *Science* is 8%. The Open Access journal *PLoS ONE* with an acceptance rate of 30 percent, is on course to publish 30 000 articles a year and currently the largest journal in the world: http://www.nature.com/news/plos-profits-prompt-revamp-1.14205

[4] "The number of college graduates in China, for example, could swell by 200 million over the next two

- The availability of (low-cost) digital technology, ICT-based software and capacities as key enablers of 'Science 2.0'.
- The growing and increasingly pressing demand for solutions to Grand Challenges (e.g. climate change, food shortage) and the societal expectation that science should deliver.
- ‘Digital natives’ becoming part of the researcher population.
- The growing scrutiny with regard to research integrity and to the accountability of science and research within societies. In this context, substantial numbers of studies appear not to be replicable.[5]

3. Implications of ‘Science 2.0

3.1 Implications of 'Science 2.0' for society and the economy

‘Science 2.0’ not only has major implications on the way science is conducted, but could also have a considerable societal and economic impact.

- The increase of transparency and openness of the international research system might lead to a higher degree of responsiveness of the research community to societal challenges.
- Benefits for society and a more robust and sound science and society relationship: more openness may also lead to more trustworthy science from the point of view of the citizen and civil society organisations (NGOs).
- Potential benefits for innovation and the economy through the uptake of results by businesses, in particular SMEs that may not have the resources to pay for access to research results.

While further research on this is needed, the potential benefits for innovation, growth and employment are considerable:

- Big and open data are estimated to add 1.9% of EU-28 GDP by 2020.[6] These gains are derived from (i) productivity increases in manufacturing and services (resulting from increased business processes efficiency), (ii) increased competition resulting from lower entry barriers for business as a consequence of the opening of public sector data, and (iii) improved allocation of production factors resulting from better decision making due to data driven management processes
- Text and data mining – a computerised research technique for the purpose of discovering and extracting knowledge from unstructured data - also has a huge

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decades - more than the entire labour force of the United States” (page 9, Word Bank Report: *China 2030, Building a modern, harmonious and creative society* (2013)).

5 This is illustrated, for example, in a lead article of *the Economist*, ‘How Science goes wrong’ (issue of 19 October 2013): “Last year researchers at one biotech firm, Amgen, found they could reproduce just six of 53 “landmark” studies in cancer research. Earlier, a group at Bayer, a drug company, managed to repeat just a quarter of 67 similarly important papers. A leading computer scientist frets that three-quarters of papers in his subfield are bunk. In 2010 roughly 80,000 patients took part in clinical trials based on research that was later retracted because of mistakes or improprieties”.

6 Demos Europe/WISE (2014): Big & and open data in Europe. A growth engine or a missed opportunity? http://www.bigopendata.eu/wp-content/uploads/2014/01/bod_europe_2020_full_report_singlepage.pdf

economic potential. The JISC report "The value and benefits of text mining" of 2012 examined potential research costs savings due to labour productivity gains that TDM may generate.

- The effect of limited access to scientific information on the competitiveness of SMEs was documented by a Danish Ministry for Research and Innovation report on access to scientific and technical information for innovative SMEs. It illustrates the difficulties that SMEs in Denmark face in accessing research articles, patent information, scientific and technical standards, technical information, and market intelligence. The report states that it takes 2.2 years longer to develop or introduce new products without speedy access to up-to-date scientific research.

- The potential benefits of better access to scientific information should be seen in the context of the high investment in Research and development across the EU. This reached €245,673 billion in 2010 (2% of GDP)[7], a rise of 43.5 % in ten years.[8] A large part of investment in research in the EU is publicly funded (35%)[9], which gives the public sector an important say in determining how results should be disseminated for the benefit of economic growth and the society at large.[10] It is therefore crucial for public authorities to define ways to improve public access to the results of publicly funded research, in order to draw the maximum benefit from Europe's investment in science.

3.2 Implications of 'Science 2.0' for the research system

The underlying idea of a principally collaborative form of science[11] is to advance science by sharing and collaborating as fast and as well as possible, rather than publishing as fast as possible in order to secure intellectual property rights on the basis of a competition among scientists. Obviously, a tension will always remain between the need for collaboration with a view to effectively achieving research objectives and the need of scientists to capitalise on and take intellectual credit for their scientific findings. Current trends reinforce the need of scientists to collaborate, and collaboration is in fact a prerequisite for mission-driven research in order to achieve a common objective. This is well-illustrated by The Human Genome Project in which scientists shared data prior to publishing (or even refrained from publishing) in order to be able to map the complete human genome in the most effective and public-good oriented fashion.

Social networking sites, such as Research Gate (currently 4 million active users) and Mendeley (about 3 million active users) enable scientists to share scientific outputs at an early stage.

These developments may lead to:

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7 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/R_%26_D_expenditure

8 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/R_%26_D_expenditure

9 http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/R_%26_D_expenditure

10 Publicly funded research refers to research undertaken by the government itself, or through grants to academic and other researchers outside the government.

11 In a way, the re-emergence of a principally collaborative form of science is a practice of the 17th century, when the whole scientific process of discovery was shared by the scientific community as soon as findings became available.

- Increasing the efficiency of science: Scientists share positive and negative results and thus considerably reduce the duplication of scientific work. At the same time, knowledge transfer among scientists and scientific disciplines is speeded up.
- Making science more productive: The early identification of dead-ends and successes drive collaborating scientists in promising directions.
- Better quality of science: The impact of false scientific claims decreases as they will be uncovered fast and thereby actively discouraged. The availability of interoperable datasets accelerates the identification of unexpected correlations and thereby facilitates new discoveries. Science might become more reliable through improved verification, re-use and quality of data.

However, the current transition of science manifests itself differently depending on scientific discipline.

3.3 Implications of 'Science 2.0' for researchers

'Science 2.0' offers an enormous potential for researchers to share knowledge, access publications and make use of data. Researchers increasingly engage in a globally networked science. This will accelerate scientific discovery and will facilitate the completion of scientific missions in a collaborative way.

The current trends in science and research mean that researchers, universities, research funders, publishers and public authorities will need to consider wide-ranging policy implications.

Researchers and research institutions need to become more aware of the different dimensions of 'Science 2.0'. For example, making research data open could become an explicit criterion for career progression. The challenge will then be to have a data strategy and data management plans developed by and for researchers. Researchers may need to be trained in curating their own knowledge resources, for example, by choosing which of the increasing options for academic publishing to use and when.

The growth of new approaches to measure the impact of research outputs is illustrated in Box 2.

Box 2 'New approaches to measure the impact of research outputs'

Altmetric.com

Altmetrics.com enables researchers and publishers to instantly visualize the online attention of a scientific paper. It monitors the research impact of scholarly articles beyond academic context.

Altmetric was founded in 2011, it is London-based and grew out of an altmetrics movement.

The first standalone version of the Altmetric Explorer, which enables scientists to measure the impact of their work, was released in February 2012. Currently, it has received investments from Digital Science and is supported by traditional publishers such as Springer.

Impact Story

Impact Story is an open source, web-based tool that provides ***altmetrics*** to help researchers measure and share the impacts of all their research outputs. This concept stands for impact assessment going beyond the consideration of traditional outputs such as journal articles, to alternative research outputs such as blog posts, datasets and software. It aims to change the focus of the scholarly reward system to value and encourage web-native scholarship. Impact Story is a non-profit organisation funded by the Alfred P. Sloan Foundation and the National Science Foundation

Impact Story has received 300.000 dollars from the National Science Foundation (USA) in order to ultimately move away from paper-based to web-based (including blogs) publication metrics.

One of the main barriers to the uptake of 'Science 2.0' practices is the attribution and quality assurance of research outputs. For research funding organisations, one of the major challenges concerns the nature of incentives. Policy challenges for funders encompass the need to identify alternative research outputs to peer reviewed papers in their assessment and funding criteria. This could include rewarding, disseminating, opening and sharing of scientific knowledge in all forms as a public good.

At universities, there will be a need to develop researcher and researcher reward schemes that reflect this approach. New assessment schemes of researchers by universities could, for example, reward open data approaches on the same scale as journal articles and other publications. Such assessment schemes could also include measures that reward collaborative ways of working. Alternative research metrics will need to be developed to measure quality and impacts of research outputs.

4. Opportunities for and barriers to 'Science 2.0'

Most of the 'Science 2.0' activities described have been driven bottom-up by researchers themselves as a result of the drivers listed above, but there are indications that policy interventions could be essential if the full potential is to be realized.

A useful way to look at this is to consider the extent to which individual researchers and teams experience opportunities and barriers relating to 'Science 2.0' activities. For example, researchers can profit from these activities because the extended networks provide a larger pool of expertise, both as project participants and as commentators on research ideas and progress. Richer data sets are also available to them. Open publication platforms allow more researchers to publish.

However, there are also barriers to the transition of science:

- Limited awareness: Although 'Science 2.0' activities are increasingly considered among scientists, many remain reticent without adequate awareness-raising.
- Lack of incentives: Academic career progression is largely dependent on peer reviewed publications. The increasingly open and collaborative nature of science makes it difficult to give credit and recognise scientific endeavour. One example is data curation and preservation, which is extremely useful in a long-term perspective, but can be very time-consuming, and is currently not yet sufficiently recognised or rewarded as an important part of the research process. A further example is that combining and sharing of data can add value to a generic area of research, rather than just individual projects or programmes. However, even if a research team recognises this, it has little direct incentive to make this wider contribution.
- Finance: Money is also an issue, for example with regard to Open Access (not all research funders will cover gold Open Access publication costs from project budgets), or in the case of data preservation, for which costly sustainable infrastructures are needed.
- Quality assurance: Researchers rely on a long-established system of peer review for quality assurance purposes. Although there are recognised and much-discussed problems in the traditional peer review system, introducing changes implies a lengthy process that can run into resistance.
- Citizen dimension: Researchers are likely to see citizen engagement as a research resource only and not to consider the additional benefits of enhanced public understanding of science.
- Fear of error: Writing about work in progress includes the risk of making mistakes. Scientists are afraid of exposing these.
- Intellectual Property Rights / protection issues: Scientists sometimes argue that publishing their work in progress would enable others to steal their ideas. This is a false issue (researchers are in no way forced to publish; they decide autonomously whether and when to publish and can patent if they so prefer), and awareness-raising and training could be needed regarding the dissemination and exploitation of research results.

This long list of possible barriers suggests that the transition of science, while essentially a bottom-up trend, may benefit from a policy-level push. Here, the policy interventions would need to reflect a holistic approach towards 'Science 2.0'.

5. The Role of research funding organisations, the Member States, and the European Union

There is a sense of urgency for having a better understanding of the on-going changes. The issue is still whether it is too late or still too early for policy interventions: the consequence of a too late intervention is illustrated by the developments of Web 2.0 where Europe lost its initial leading position. Too early intervention could, however, lead to stifling creativity and entrepreneurship. This could entail a policy approach of 'no-regret' policies as well as stakeholders developing their positions without direct policy interventions.

5.1 Science in Transition: evolving debates and activities in the Member States of the European Union

Although 'Science 2.0' affects the entire scientific process, discussion on developments related to 'Science 2.0' at the international level and in Member States have most often focussed on particular elements of 'Science 2.0'. For example, *The San Francisco Declaration on Research Assessment (2012)* recognizes the need to improve the ways in which the outputs of scientific research are evaluated and, in particular, the bibliometric evaluation of research outputs is subject to debate with a call to reduce the use of journal impact factors. By June 2013, well over 10,000 scientists and well over 400 institutions, from which almost 50 percent are European, had signed up to this declaration.[12]

Debates in Member States of the European Union are either focussed on particular elements of 'Science 2.0', predominantly issues of Open Access (publications and data), or have taken shape in the context of particular initiatives of public authorities. In the UK, for example, The Royal Society has published the report *Science as an Open Enterprise* in 2012. This report highlights the need to grapple with the huge deluge of data created by modern technologies in order to preserve the principle of openness and to exploit data in ways that have the potential to create a second open science revolution.[13]

In the Netherlands, an intensive debate has evolved on the basis of a position-paper entitled 'Science in Transition'. The ongoing debate in the Netherlands addressed, among other, the issue of the use of bibliometrics in relation to the determination of scientific careers. However this debate went actually beyond the scope of what is described in this consultation paper as 'Science 2.0' and included also discussions on the democratisation of the research agenda, the science-policy interface and calls for making research more socially relevant.[14]

The debates in Member States of the European Union and the obvious global dimension indicate that any public policy at the European level has to be grounded in an EU wide coordination among all Member States.

5.2 The role of Research Funding Organisations

Research funding organisations may need to consider new ways of financing and evaluating research acknowledging 'Science 2.0' based research outputs. This could include reviewing the evaluation criteria of research proposals and the procedures of quality assessment.

Furthermore, research funding organisations may need to improve the communication of research data from the projects that they fund by recognising those who can maximise usability and good communication of their data. This could be done by including the costs of preparing data and metadata for curation as part of the costs of the research process.

Currently, the European Commission funds Citizen Science projects. Open Digital Science is also foreseen as a cross-cutting issue under the EU Framework Programme for Research and Innovation Horizon 2020 and its projects to develop e-infrastructures, and more specifically Virtual Research Environments, and support for digital science projects

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[12] See: http://am.ascb.org/dora/

[13] The report can be downloaded at: https://royalsociety.org/policy/projects/science-public-enterprise/Report/

[14] See: www.scienceintransition.nl (with a report on the state of affairs of June 2014)

are underway. Further policies could be articulated by inserting messages on ‘Science 2.0’ under the strategic programming of the EU Framework Programme for Research and Innovation Horizon 2020 and more opportunities for Citizen Science, including responsible research and innovation.

5.3 The European Research Area and stepping up on Open Access policies

The European Union has the objective of strengthening its scientific and technological bases by achieving a European Research Area (ERA) in which researchers, knowledge and technology circulate freely. ERA policy and structural reforms should help use limited resources more efficiently and therefore maximise the return on investment in research, while increasing its effectiveness at national and EU level. Besides other objectives, such as increasing the effectiveness of national research systems, transnational cooperation, establishing an open labour market for researchers and achieving gender equality and mainstreaming in research, optimal circulation and transfer of scientific knowledge is essential in ERA. Publicly funded knowledge must be available for researchers and the private sector to enhance the knowledge base, diminish regional discrepancies and promote innovative solutions to societal challenges. Unrestricted and free of charge access to publications is backed by a growing number of universities, research centres and funding agencies across Europe. Almost all Member States have set up legal and administrative conditions in support of Open Access to publications, and some of them are also promoting Open Access to data.[15]

These are key elements of ‘Science 2.0’. The European Commission, thereby, sees Open Access not as an end in itself but as a tool to facilitate and improve the transparency, the circulation of scientific information in Europe and ultimately, contribute to better policy making.

Therefore, a comprehensive policy package containing a series of measures to improve access to scientific information produced in Europe was adopted at the end of 2012.[16] Furthermore, Open Access to publications is now mandatory and a Pilot on Open Research Data has been launched under the EU Framework Programme for Research and Innovation Horizon 2020.

In general, Open Access needs to be considered in a broader context and needs to include a change in the scientific culture towards more openness. This could be achieved through encouraging and incentivizing Open Access, e.g. through integrating it in researcher career evaluation (see for instance the approach of Liege University where only publications deposited in the university repository are taken into account in their career evaluation).

‘Science 2.0’ dynamics will further expand Open Access requirements and might challenge, in the mid-term future, the dominant model of publishing in subscription-based journals (e.g. by shifting towards publishing ‘papers’ in different types of repositories).

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15 Commission SWD “ERA Facts and Figures 2013”, p. 28

16 Communication 'A Reinforced European Research Area Partnership for Excellence and Growth' COM(2012)392; Communication, 'Towards better access to scientific information' COM(2012)401; Commission Recommendation on access to and preservation of scientific information COM(2012)4890).