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Research for environmental policymaking: how to prioritise, communicate and measure impact

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Research for environmental policymaking: how to prioritise, communicate and measure impact

Contents

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Image page 4: Courtesy of Richard Klavans and Kevin Boyack.

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EDITORIAL

How to decide on research policies for the environment?

Up-to date scientific and technological research is vital to allow humans to adapt appropriately to our changing global environment, and current rates of environmental degradation and resource depletion. Effective research policies are essential to maintain or improve the standard of life for future populations – in Europe and globally.

But there are some tricky questions. First, what subject areas or problem areas are the most important or urgent to understand? Increasingly specialised research often undertaken within disciplines is valuable but may be limited: for instance, if connections with phenomena studied by others are omitted or downplayed. This begs a second question: what is the value of incentivising inward-looking specialisation? And, third, how should this be balanced with outward-looking interdisciplinary research to offer a more networked understanding of our environment and situation?

The role of national, EU and international research policies is particularly important. Any initial decisions can set the parameters for later innovations and thus significantly contribute to the shaping of the economy and creation of jobs and new technologies. Appropriate priorities for funding, measuring the impact of funded research and communicating research results more widely will ensure the greatest positive impact for communities and their environment. It is also crucial to establish the mechanisms by which scientific knowledge is currently used in policy creation – to understand how these might be improved in future.

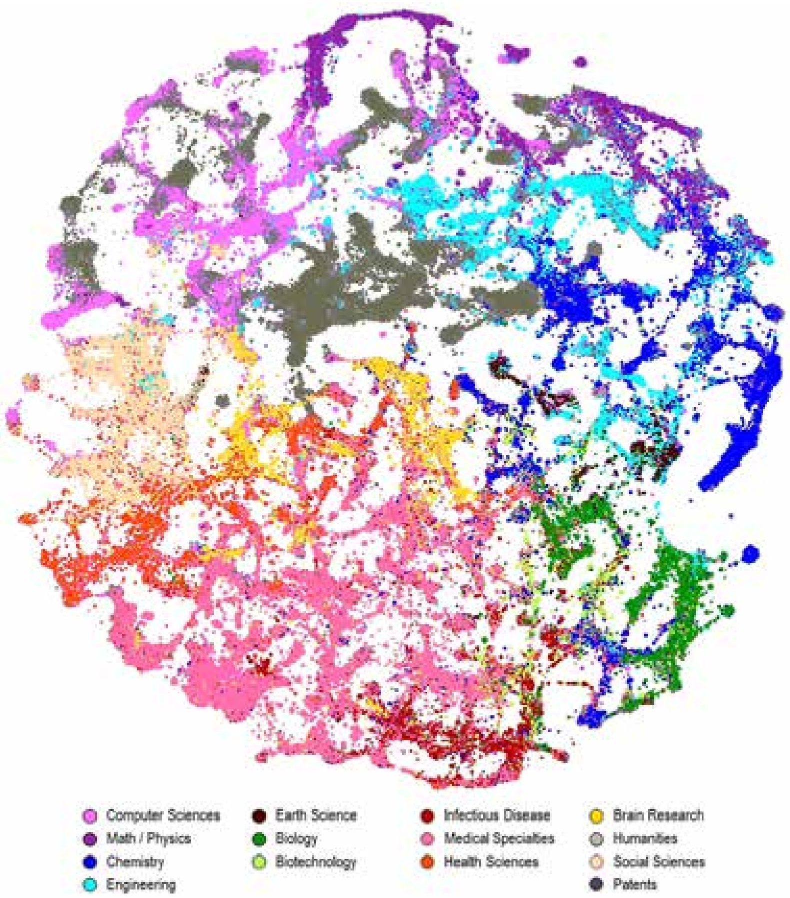
This Thematic Issue aims to increase understanding of the core questions above. It emphasises some of the latest research about identifying appropriate emerging areas of science — vital information for policymakers, scientists, decision makers in industry, funding bodies and the public. To this end, it presents studies on methods to understand and improve the links between scientific knowledge and its real-world application in policy, on topic identification for funding and on research impact and dissemination.

Effective dialogue between those working in science and policy spheres is essential when creating guidance or regulation on complicated environmental topics. The current alarming loss of biodiversity is a multifaceted problem that cannot be addressed by scientists or policymakers alone. Practical ways to encourage communication between scientists' and policymakers' priorities to protect biodiversity are examined in the article '**Conversations for conservation: the importance of interactive dialogue**'. UK researchers have provided a list of recommendations for better communication between scientists and policymakers. These include fundamental changes such as promoting the co-production of knowledge between the two roles and formulating cross-disciplinary research.

Specialised, expert advice can be highly valuable when making complex policy decisions, for example, when determining scientific research priorities. In '**Evaluating expert involvement in policymaking**', following a systematic review of the literature, the researchers found that experts are involved in policymaking via methods that are often not explicitly justified. They also found that the interaction and impact of expert involvement is rarely evaluated. The researchers suggest that a method of engagement could be chosen based upon the features of the policy issue — e.g. how much uncertainty or consensus is involved — and that defining clearer goals would help with evaluation of these processes. They propose a framework to help identify the most relevant methods of consulting experts in particular situations, which could lead to a better transparency of methodology. This would result in better opportunities to improve the profound processes that shape the research and technological landscape.

Technologies that provide solutions to environmental problems comprise one of the fastest-growing global markets, reaching a value of approximately €678 billion in 2013. Following a survey and panel workshops, the article '**Eco-technologies: priorities for the future**' recommends how future funding in environmental technology research and development should be spent, emphasising flexible, cost-effective solutions. The study suggests that Europe should concentrate more research funding on exportable environmental technologies to meet the future needs of countries with developing economies. It concludes that funding should not be predominantly technology-oriented but problem-oriented, therefore helping to tackle the broad range of contributing factors to many environmental problems.

The article '**Mining scientific databases for emerging topics: a new tool for policy**' contributes a new method to search and utilise data within scientific databases. This method assists in the identification of emerging topics for research, and thus the allocation of funds and the determination of research priorities. The authors say it could also provide insights into early indicators of emerging events and contribute to an understanding of how science and technology evolve.



Improving the identification of emerging research topics could assist research planning strategies. In '**Creating a map of science: a visual representation of global research**' researchers have created a map which is based on links to almost 20 million scientific articles published over the past 16 years. The map clusters and links scientific disciplines by citation-based relationships. Adding information about funding sources would better enable the model to forecast the direction in which research is heading. Currently, the researchers intend it to be used to help distinguish — and even predict — the research areas in science which have longevity, and those which are innovative.

Scientists are increasingly being asked to demonstrate 'impact', inspiring discussions about what impact means, and how it can best be evidenced. In '**Broader impacts are important when measuring the utility of science**', researchers propose that the trend to measure impact as the number of new commercial opportunities generated is inadequate for evaluating the full benefits of science. Using research from the Chalmers Energy Initiative (CEI), a large research programme on biomass, electric transport and large-scale renewable energy systems, they look at the broader impacts of seven key activities performed by academic researchers. These include research, education, scientific publishing and explicit guidance. The researchers focus on how the activities relate to seven functions – such as knowledge development and diffusion and entrepreneurial experimentation. The researchers assessed the relationship between the activities and functions through case studies and advise that research assessments should be framed by a broader idea of impact. They also offer recommendations for four key activities, along with relevant metrics, which could provide a more comprehensive reflection of academic research value.

Public-funded research in particular needs to focus on its ability to positively impact — i.e. increase the benefits to — society. Funding bodies in the UK justify the monies allocated to research projects with impact-based assessments — which generally have a strong economic imperative. However, the researchers in the article '**Changing research assessments could encourage knowledge dissemination**' argue that research assessments should focus more on engagement processes and less on impacts and outcomes. They say the current emphasis is of contested value, and posit that it does not provide sufficient incentives or guidance for future research. This study examines researchers' intended impacts and motivational factors. It suggests that a change in research evaluation methods, combined with better direction from university managers, could help incentivise better knowledge exchange and engagement between departments and non-academic entities.

Online media platforms have become an important feature of science communication. The article '**Creating 'buzz' for impact: Twitter and new media science communication**' analyses the communication activities of a group of scientists working in nanotechnology, to determine how different forms of outreach are related to scientific impact. The study's key conclusion is that public communication can contribute to scientific impact in a measurable way. It also suggests that social media could supplement traditional approaches to measuring the impact of academic work.

Disseminating research quickly and appropriately is essential for communicating the results of scientific research, especially when responding to a complex challenge such as climate change, which involves coordination between different levels and sectors. Researchers for '**Internet tools for research dissemination: a climate change case study**' examine the role of web-based tools in circulating the findings of a research project which studied community-level climate change innovations in Canada. The study provides insights on how best to use the Internet to communicate the outcomes of scientific research. It also recommends that researchers wishing to effectively communicate their findings should establish a web presence; think about how the public likes to engage with their field of science; consider how practitioners (e.g. policymakers) use media; and be aware that different media types attract different audiences. The researchers emphasise the continued and sustainable building of audiences for research messages — something that is not often accounted for within project cycles.

Pointing the best way towards future research developments is not an easy task. However these issues of impact, emerging topic identification, and communication are central in the formation of effective strategies to adapt to our changing world. We hope this Thematic Issue will give increased focus to the tools, techniques and prioritisation methods that will allow the future development of strategic EU and international research and innovation policies, and support better planning for the future.

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Read more about: Biodiversity, Environment information services, Sustainable development and policy assessment

Conversations for conservation: the importance of interactive dialogue

To ensure biodiversity research is better used in decision-making, scientists and policymakers need to interact more effectively. Through a literature review, interviews and a workshop with key stakeholders, this study provides recommendations for achieving a better dialogue.

"This study, completed as part of European project SPIRAL[2], aimed to find practical ways to encourage effective dialogue between science and policy in order to protect biodiversity."

Biodiversity is declining at an alarming rate. Recent estimates reveal an exceptionally rapid loss over recent decades, indicating that a sixth mass extinction may already be underway[1]. Although we know more than ever about biodiversity — its trends, its drivers and where action is needed — conservation continues to be given low priority compared to other policy challenges. There is a perception, say the researchers, that knowledge on loss of biodiversity is under-used in decision making.

This study, completed as part of European project SPIRAL[2], aimed to find practical ways to encourage effective dialogue between science and policy in order to protect biodiversity. As part of a project with collaborators from Europe and beyond, researchers from the UK combined insights from published studies and interviews with a workshop with people from Belgium, Finland, Spain and the UK working at the biodiversity science-policy interface.

The first part of the study involved a literature review to identify the key challenges to effective science-policy dialogue. The review shed light on the modes of science-policy communication, such as the traditional 'linear model', in which questions and credible enquiry need to be well-defined and scientific facts are provided to policy advisors to develop solutions based on this knowledge. The researchers suggest that this simple model does not reflect the systemic nature of the issue or the complexity involved in transforming the results of scientific enquiry into useful policies. They also identified the 'silo mentality' in science and policy (an attitude where institutions or departments do not share information between each other), which they say has become another challenge to effective policymaking. Silo thinking is a problem for scientists as well as policymakers. As biodiversity loss is a complex, multi-dimensional problem, the researchers recommend that policymakers move beyond silos to encourage the issue to be taken into account in broader policy sectors. They say that biodiversity scientists need to diversify from their regular contact with decision makers in environmental policy and create new relationships with departments which are responsible for areas such as economic policy, which is partly responsible for biodiversity loss. Biodiversity scientists could also spread their knowledge to audiences which are less informed about the issues, such as economic sectors.

The outcomes from the review were used to inform a series of interviews with the producers (e.g. scientists) and users of knowledge (e.g. policymakers). The 25 interviews were recorded and transcribed verbatim for qualitative analysis, using a software programme to analyse the data. From the results of the interviews, a draft set of recommendations was developed.

1. Ceballos, G., Ehrlich, P., Barnosky, A., Garcia, A., Pringle, R. and Palmer, T. (2015). Accelerated modern human-induced species losses: Entering the sixth mass extinction. Science Advances, 1(5), pp.e1400253-e1400253.

2. Science Policy Interfaces for Biodiversity Research Action and Learning (SPIRAL) is supported by the European Commission under the Seventh Framework Programme. See: http://www.spiral-project.eu/

SPIRAL Project Handbook: http://www.spiral-project.eu/sites/default/files/The-SPIRAL-handbook-website.pdf

Source: Young, J., Waylen, K., Sarkki, S., Albon, S., Bainbridge, I., Balian, E.; Davidson, J., Edwards, D., Fairley, R., Margerison, C., McCracken, D., Owen, R., Quine, C., Stewart-Roper, C., Thompson, D, Tinch, R., Van den Hove, S. & Watt, A. (2014). Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodiversity and Conservation*, 23(2), pp.387-404. DOI: 10.1007/s10531-013-0607-0. This study is freely available at: http://link.springer.com/article/10.1007%2Fs10531-013-0607-0

"A move away from silo thinking in science and policy is essential in order to start creating alliances between science, policy and eventually, society, to meet the environmental challenges of the 21st century."

In the final stage, these recommendations were tested and refined in a workshop involving 18 individuals with diverse roles in science and policy. Participants received the draft recommendations derived from the interviews before the workshop took place. Discussion at the workshop concentrated on examining these ideas and identifying themes. This allowed the researchers to develop a set of further recommendations to improve knowledge transfer within individuals, teams and organisations:

- For individuals and teams, the study recommends planning events where disciplines, backgrounds and sectors can meet, setting up projects to account for science-policy communication, and to consider cross-review (e.g. policymakers reviewing policy outputs). For scientists specifically, they recommend adapting communication approaches according to the audience, prefacing reports with accessible summaries, consider writing reviews and policy briefs and seek opportunities to learn about policy processes.

- For those working in policy the study recommends they keep up to date with relevant scientific news, recognise that scientists are a diverse group (and often highly specialised) and therefore do not have knowledge of all issues relating to biodiversity, and to be transparent and open to discussion.

- For organisations the recommendations include supporting interdisciplinary research, providing incentives for interactions between science and policy and funding training to build science-policy relationships.

It is important to recognise that biodiversity loss is a multifaceted problem that cannot be addressed by science or policy alone. Therefore the authors recommend a series of fundamental changes that should be taken to tackle the loss of biodiversity through enhanced science-policy communication:

1. Scientists need to communicate the relevance of biodiversity to both the public and policy sectors, as sometimes loss of biodiversity is not visible, unless it involves charismatic species. This could be done by focusing on the benefits of nature to the human race – underpinned by biodiversity. However, it is important to avoid the commodification of nature and the message should be altered for different groups. Scientists also need to avoid communicating a simplistic explanation of biodiversity loss — as it is a complex multi-dimensional problem.

2. Scientific research and engagement need to be made obvious for policy and other target audiences. Promoting a two-way interaction between scientists and policy from an early stage and framing research and policy together will help sustain interest and commitment in all involved.

3. Policymakers need to communicate their priorities to scientists. This will enable scientists to produce relevant and suitable research for practical use.

4. A move away from silo thinking in science and policy is essential in order to start creating alliances between science, policy and eventually, society, to meet the environmental challenges of the 21st century.

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Evaluating expert involvement in policymaking

Expert advice can be crucial for good decision making. This study reviewed how experts are involved in policy, and the results of their involvement, finding that certain involvement processes are more suited to specific types of policy questions, and that more robust evaluative and documenting processes are needed. The researchers propose a framework to identify appropriate consultation methods for specific policy questions.

"This study aimed to understand expert involvement better, focusing on the methodologies of expert involvement and its potential policy impact."

How best to utilise the expertise and opinions of experts[1] when developing policy is a key issue for decision makers, as their experience, depth of knowledge and judgement are highly valuable for complicated questions, such as setting priorities for research. Yet, how experts are involved in policy development and the outcomes of their involvement has not been documented precisely. This study aimed to understand such expert involvement better, focusing on the methodologies of expert involvement and its potential policy impact.

A systematic review of scientific publications was used to identify relevant papers. A total of 103 papers were identified, including 157 individual studies, which were published in 85 different journals using data from 52 different countries. Most papers reported on a single study using data from one country, and most were related to environmental policy (followed by research in public health, agriculture and food safety).

Qualitative analysis of the articles revealed only a narrow range of methods for expert involvement. Furthermore, the choice of the involvement method was rarely justified, and there was little evidence of evaluation of the expert involvement process or its policy impact. In fact, of all the papers assessed, only 12 evaluated the process of consultation, and less than half provided a critical assessment of the methodologies applied.

Five principal methods were used, either involving one-way (questionnaire and interview) or interactive communication (workshops, focus groups and the Delphi method, in which a panel of experts answers questionnaires in rounds, based on input from the previous round). Experts were consulted on an individual basis using interviews or questionnaires, or as part of groups using workshops or focus groups. The Delphi is a 'hybridised' method, as it allows for both individualised and group consultation.

Significantly, the choice of method was generally based on practical reasoning rather than because it was the best fit for the characteristics (e.g. uncertainty) or goal of the policy. Alongside this, the authors also identified limited evaluation of policy impact and a lack of quality control.

The researchers suggest that experts could be involved based on the characteristics of the issue (e.g. how much uncertainty is involved, are experts in agreement?) and the goal of the exercise (e.g. is it to provide decision support, or to gather existing opinions?). As a result, they present an alternative basis for choosing an expert involvement method, based on the policy scenario at hand.

Source: Fischer, A., Wentholt, M., Rowe, G. & Frewer, L. (2013). Expert involvement in policy development: A systematic review of current practice. *Science and Public Policy*, 41(3), pp.332-343. DOI: 10.1093/scipol/sct062

1. Expert: defined here as 'someone who has gained domain-specific expertise through their profession'
Source: Fischer, A., Wentholt, M., Rowe, G. & Frewer, L. (2013). Expert involvement in policy development: A systematic review of current practice. Science and Public Policy, 41(3), pp.332-343. DOI: 10.1093/scipol/sct062

The suggested methods most likely to deliver the relevant information can be classified according to specific situations:

- **Consensus seeking:** in cases where there is high ambiguity but little uncertainty regarding the potential impacts of a decision, consensus may be needed. Use of a workshop is recommended for the free exchange of information and opinions, before reaching consensus, or tolerating differences.

- **Distant consensus seeking:** when consensus is needed but experts cannot meet in person, the use of teleconferencing may be appropriate.

- **Consensus seeking and boundary setting:** if the expert opinion is ambiguous and there is uncertainty regarding policy outcome, boundaries should be set to determine when and how information will influence policy. Here, interactive methods such as workshops or the Delphi method can be useful.

- **Confirmation poll:** where expert legitimisation is needed in situations of low ambiguity and uncertainty, opinion polling can be useful, especially when many experts need to be consulted in a short time frame.

- **Anonymised consensus seeking:** in situations where a policy issue is controversial, anonymised polling may be appropriate, or anonymised Delphi, which enables interactive but anonymous discussion.

- **Vote:** if there is disagreement among experts and resolution is required in a short time frame, voting can identify the majority opinion.

These recommendations could improve practices and increase transparency and iterative evaluations of methodologies in policymaking, which may lead to more appropriate priorities for research, as well as increasing the likelihood that outcomes are trusted and accepted by expert and non-specialised stakeholders alike.

"These recommendations could improve practices and increase transparency and iterative evaluations of methodologies in policymaking, which may lead to more appropriate priorities for research…"

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Themes: Environmental technologies, Sustainable consumption and production

Eco-technologies: priorities for the future

Priorities for future environmental technology research and development were outlined by a study that surveyed experts in the field in 2010-11. The global environmental problems and potential solutions that new technologies could provide were identified and discussed in questionnaires and workshops. One of the main recommendations of the study was for a greater focus on flexible and cost-effective innovations that could alleviate potential environmental issues in countries with developing and emerging economies.

"...future technologies which aimed to solve the most pressing environmental problems were deemed as those that had the greatest market potential."

Technologies that provide solutions to environmental problems are one of the fastest growing worldwide markets, reaching a value of approximately €678 billion in 2013. The term 'environmental technology' includes not only products, but also concepts, techniques and services that could mitigate environmental damage or aid the recovery of already damaged environments.

The researchers identified the most pressing future environmental concerns and promising technological developments through literature reviews, online research, and surveys and workshops with specialists in related areas of industry, academia and policymaking. Seventy-seven technological solutions were identified and grouped within four environmental categories: 20 in climate protection and air pollution control; 18 in soil conservation and biodiversity; 23 in protection of scarce resources and waste management; and 16 in water management.

The questionnaire, which asked participants to rate the level of global and national pressure on environmental issues, and the development needs, market potential and overall importance of selected technologies was completed by 440 specialists involved in environmental technology research, policy and economics. The results of these surveys were then discussed and analysed by a select panel in four topic-specific workshops.

The researchers found that there were perceived to be higher global pressures to act on all of the issues than local pressures. For example, the pressure to act on water management was rated by 91% of respondents as 'very high' or 'high' on a global level, but was similarly rated by only 42% of respondents when asked about pressures specifically within Germany. Another marked discrepancy was in air pollution control, which was rated as 'very high' or 'high' by 67% on a global level, compared with 44% on a local level.

Accordingly, future technologies which aimed to solve the most pressing environmental problems were deemed as those that had the greatest market potential. For industrialised countries, these technologies were in the areas of energy efficient lighting; solutions for building insulation; lightweight materials for construction; and energy efficient drives and waste heat recovery in industrial processes. By contrast, the highest ranked potential technologies in low-income countries were in the areas of water management — in particular, agricultural irrigation and sea and brackish water desalination using renewable energies; cooling and conditioning of buildings; and developing technologies that are focused on adapting to climate change.

Constraints on the progress of new technologies were listed as 'unsolved technical problems' and 'missing R&D capacities', whereas constraints on established technologies were

Source: Weinberger, N., Jörissen, J., Schippl, J. (2011). Foresight on environmental technologies: options for the prioritisation of future research funding – lessons learned from the project "Roadmap Environmental Technologies 2020+". *Journal of Cleaner Production 27*: 32 – 41. DOI:10.1016/j.jclepro.2011.12.038 http://dx.doi.org/10.1016/j.jclepro.2011.12.038

"locally important initiatives... were said not to be held back by technological limitations, but by a lack of appropriate policy interventions, such as incentive systems, legal structures, and raising public awareness."

'counterproductive political regulations' and 'missing social acceptance'. Additionally, locally important initiatives such as biodiversity monitoring, soil improvement and the reduction of ecosystem fragmentation were said not to be held back by technological limitations, but by a lack of appropriate policy interventions, such as incentive systems, legal structures, and raising public awareness.

There were some notable limitations to the study. Although the survey and subsequent discussions included problems faced by countries around the world, only German-based specialists were consulted. Another caveat was that technologies regarding energy generation, conversion and use were not included, a restriction set by the funders of the study.

The authors noted that high-tech products developed for the European market are often not applicable in emerging and developing countries, and suggested that Europe should concentrate more research funding on exportable environmental technologies to meet the future needs of emerging and developing countries.

They also suggested that future funding should not be predominantly technology-oriented but problem-oriented, therefore supporting inter-departmental work and helping to tackle the broad range of contributing factors to many environmental problems.

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Read more about: Environmental technologies, Environmental information services

Mining scientific databases for emerging topics: a new tool for policy

Identifying emerging research areas and technologies is important for decision makers, but notoriously difficult to do. This study presents a new way of searching the literature to identify emerging topics, which will help policymakers, industry and funding bodies to make better decisions..

"Identifying emerging and innovative areas of science is important for policymakers, scientists, decision makers in industry, and funding bodies. It can help to direct research priorities, identify which areas of science should be included in funding programmes and devise innovative technologies."

Identifying emerging and innovative areas of science is important for policymakers, scientists, decision makers in industry, and funding bodies. It can help to direct research priorities, identify which areas of science should be included in funding programmes and devise innovative technologies. Efforts in this area have expanded in recent years, evidenced by the European Commission's Future & Emerging Technologies programme, which was set up to invest in 'frontier research'.

Although this is an area of increasing policy interest, most attempts to assess emerging technologies have been retrospective and case study-based, and therefore unable to identify the presently emerging topics that are of greatest interest to decision makers.

In this study, researchers developed a new method for identifying emerging topics in science and technology, which overcomes some of the limitations of previous approaches. Their technique can pick out emerging topics from citation databases, and in this study was applied to identify over 70 emerging topics.

The method was applied to the Scopus database (1996–2010) the largest abstract and citation database of peer-reviewed literature. The researchers 'clustered' the database in two ways: co-citation (when two documents are cited together by another document) and direct citation (when one document is cited by another).

The researchers used these clustering methods to create two different models. The co-citation model was developed by forming clusters of cited papers for each year in the database. Papers published in a given year were assigned to clusters of references, based on their bibliographies. Each cluster therefore comprised papers from the current year and the group of references that most informed the work, based on their bibliographies. On average, clusters contained 14 current papers (those published in the current year) and 25 reference papers (published previously, but used to inform the current paper). Finally, clusters from different years were linked based on the references they shared (to create 'threads').

The direct citation model is more straightforward. Direct citation clusters were formed based on citation links between articles using the full set of Scopus articles and in a single clustering process. This provides a broad overview of growth for a topic, while co-citation provides a more detailed picture.

Source: Small, H., Boyack, K. & Klavans, R. (2014). Identifying emerging topics in science and technology. *Research Policy*, 43(8), pp.1450-1467. DOI: 10.1016/j.respol.2014.02.005

"The findings show that citation-based methods can be used to identify emerging topics in science and technology successfully."

The researchers identified the clusters that were most emergent — across both models at the same point in time — using a mathematical function that calculates 'emergence potential'. The function selects for new direct citation clusters with high growth rates whose papers are also in new co-citation threads for a given year. In other words, clusters that are new and rapidly growing are classified as the most emergent.

The method was applied to papers published in the years 2007–2010 to identify the top 25 emerging clusters for each year. Over the four years, this comprised a total of 71 individual topics, which included subjects as diverse as iron-based superconductors, swine flu, diabetes, graphene, personalised cancer management and cloud computing. Some topics were in the top 25 for three years (iron-based superconductors, induced pluripotent stem cells, and cardiovascular events in type 2 diabetes) and two topics appeared in all four years (social tagging and spectrum sensing in cognitive radio).

After identification, the topics were classified by discipline: medicine and life sciences (the best represented), computer science and engineering, and physical and chemical sciences. The topics were also characterised by the reasons for their emergence: scientific discovery, technological innovation, or exogenous (external) factors. Scientific discovery describes areas where a new finding is made or fundamental knowledge is gained, while innovation describes cases where existing science is used to create new devices. Finally, exogenous factors can be in addition to the previous two reasons, and describe factors such as health threats or government initiatives.

Scientific discovery was the most prominent factor among emerging topics, identified in 62% of topics. An example is iron-based superconductors (physical and chemical sciences), which were the result of the discovery of superconductivity in a new class of materials. Innovation drove the remaining 38%, such as wireless sensor networks (computer science and engineering), which can find low power sensors in a physical environment and represent a new use of wireless technology. External factors were present in just over half (56%) of all topics, of which government action (i.e. reports, hearings, agency targets or funding programmes) was the most prevalent. For example, the 'comparative effectiveness of medical treatments' (medicine and life sciences) topic was the subject of a US congressional report in 2007 and received over $1 billion of funding from the American Recovery and Reinvestment Act in 2009, which likely contributed to its emergence.

The findings show that citation-based methods can be used to identify emerging topics in science and technology successfully. Importantly, they also show that this is possible using global data analysis, as opposed to the local and case study-based approach used to date.

The study contributes a method to search and utilise data within scientific databases and provides a solution to the longstanding problem of identifying emerging topics. It may help to better allocate funds to research and determine research priorities. The authors say the method could also provide insights into the process of emergence itself, which may in turn lead to early indicators of emerging events and contribute to an understanding of how science and technology evolve.

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Creating a map of science: a visual representation of global research

A map of science could assist research planning strategies by helping to identify emerging topics. The map – which is based on links to almost 20 million scientific articles that have been published over the past 16 years – clusters and links scientific disciplines by citation-based relationships and serves as a highly detailed and scalable infographic. The authors hope it will be used by research planners to help distinguish – and potentially forecast – the research areas in science which have longevity, and also those which are innovative.

"Classification takes place by data mining and then partitioning sets of documents into discipline-based groups, such as chemistry, medical science, earth science, etc., and determining the relationships between these groups."

Creating a map of science requires a combination of classification and visualisation. Classification takes place by data mining and then partitioning sets of documents into discipline-based groups, such as chemistry, medical science, earth science, etc., and determining the relationships between these groups. This information is then used as an input to a system which can visually simulate the information in an easily digestible way.

The first attempt to make a worldwide map of science using citation-based techniques in the 1970s used 1 310 highly cited references from a single year. The next step was taken in 1999, when a four-level map was created from 130 000 reference papers. In 2006, co-citation models were made from 700 000 papers, and throughout the rest of the decade, several models were created using data sets of millions of citing papers spanning several years. This particular map draws on nearly 20 million scientific documents.

The model is based on a co-citation technique, which is a way of determining similarities and relationships between articles. The thresholds that were used to determine co-citation sources were adjusted to achieve greater scope – from the most emergent to the most persistent topics – and the technique was combined with bibliographic coupling to find relevant articles that co-citation methods alone may have missed. The process was enhanced with an additional step that directly analysed the texts of the articles for relevant keywords.

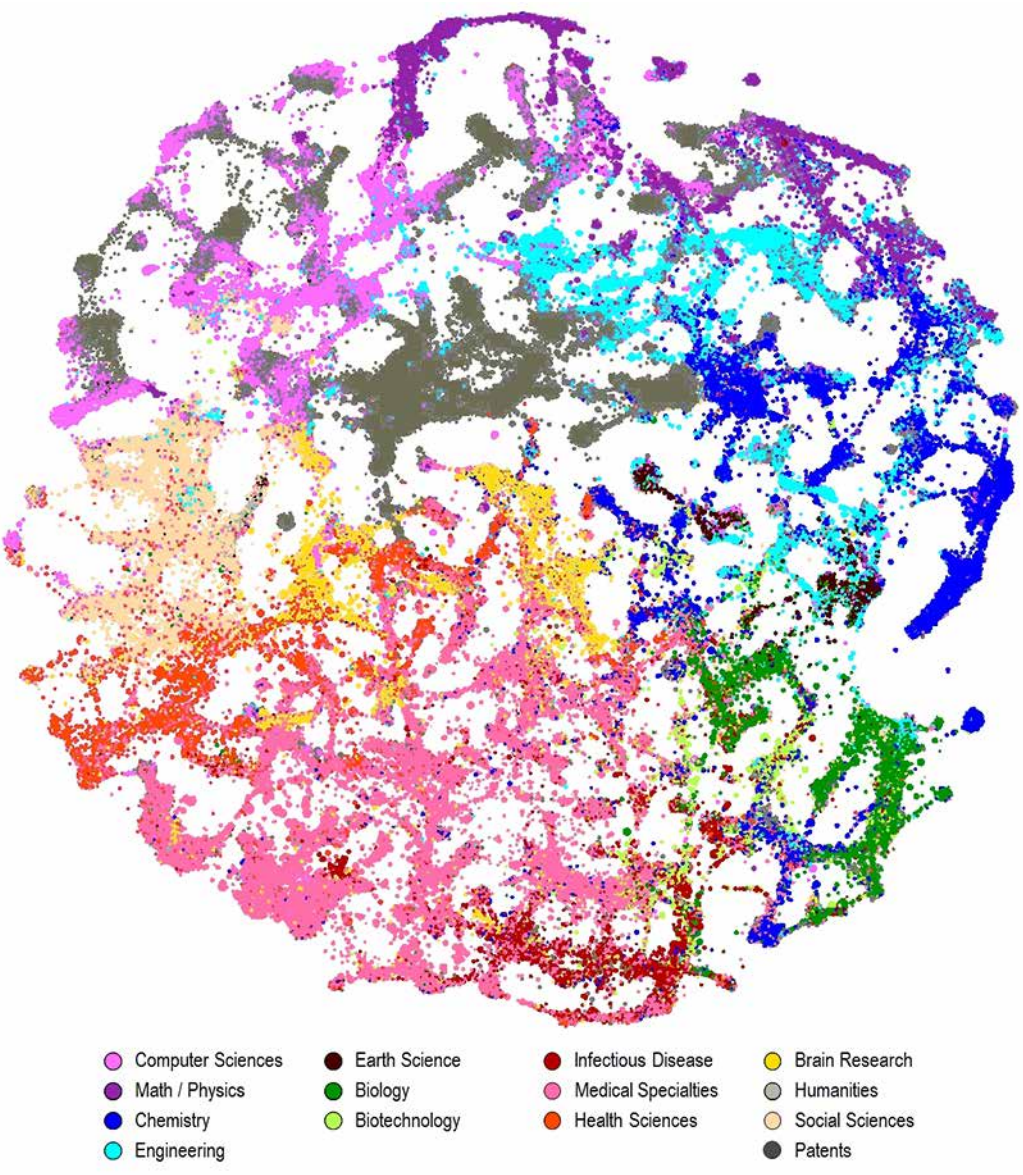
The visual mapping of the data set was done by the OpenOrd algorithm to draw intricate layouts of hundreds of thousands of groups. Inputs to the algorithm were further tweaked to achieve the best visual communication of the data, which resulted in an integrated multicoloured map with networked strands, which can be viewed as a whole or scaled up to specific levels of detail.

The map can help define the characteristics of certain topics within science. For example, 'superconductivity' and 'elementary particle physics' have low growth rates, long durability and are related strongly to specific disciplines, whereas 'environmental, energy and economic policy' and 'sleep' have high growth rates, are more temporary, and are multidisciplinary. As a general rule, growth rates tend to correlate inversely with stability, and just under one third of papers published each year are not followed up the next year.

Source: Boyack, K.W., Klavans, R., (2013). Creation of a highly detailed, dynamic, global model and map of science. *Journal of the Association for Science and Technology 65(4)*: 670 – 685. DOI 10.1002/asi.22990

"The addition of information about funding sources would also better enable the model to forecast in which direction research is heading.."

The authors note that much could be done to improve and expand the model[1] to make it more globally representative. Documents regarding patent applications have only recently been added, and the authors suggest that the inclusion of scientific and technical databases in other languages, notably in Chinese, might dramatically change the layout of the map. The addition of information about funding sources would also better enable the model to forecast in which direction research is heading.



1. In a later study in 2014, the same researchers more than doubled their original map of science. They compared two maps of science, one simply based on source documents, and the second, which uses secondary source items (such as journal articles from non-indexed sources, conference papers, books and government reports, software, and even newspaper articles) found on Scopus, over a 16-year period. None of these items have an indexed link on the database. The map has now expanded from including 19 to 43 million documents. The inclusion of secondary source items strongly enhances the position of social sciences in relation to the natural sciences and medicine and gives them a more central position in the map. Boyack, K. W., & Klavans, R. (2014). Including non-source items in a large-scale map of science: What difference does it make? Journal of Informetrics, 8, 569-580. http://dx.doi.org/10.1002/asi.22990

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Broader impacts are important when measuring the utility of science

Governments and funding bodies are increasingly evaluating the 'impact' of academic research. There are growing discussions about impact – what it means, and how it can be demonstrated – and it is a challenge to evaluate impact on society. This study investigated the broader benefits of scientific research, beyond technology development, to support more comprehensive evaluations of science.

"...what constitutes 'impact' is evolving. A growing belief, in Europe and elsewhere, is that impact can be measured by the number of new patents or spin-off companies generated by a research project, while others propose that research generates benefits far beyond commercialisation."

Scientists are increasingly being asked to demonstrate the 'impact' of their research, particularly to gain funding. Indeed, recent efforts by several European governments to introduce 'performance-based funding' place a greater emphasis on 'impact' than ever before. In the UK for example, impact makes up 20% of the Research Excellence Framework (the way in which research in UK higher education institutions is assessed).

However, what constitutes 'impact' is evolving. A growing belief, in Europe and elsewhere, is that impact can be measured by the number of new patents or spin-off companies generated by a research project, while others propose that research generates benefits far beyond commercialisation.

There is a risk that by focusing on the former, the criteria used to assess research may neglect vital aspects of science's value. Research generates many outcomes that are not directly measurable: ideas, opportunities and knowledge, for example.

To assess this risk, this study assessed the outputs of the Chalmers Energy Initiative (CEI), a large research programme that received Strategic Research Funding from the Swedish Government in 2010. The researchers wanted to investigate how science is made 'useful' at the CEI, and to use these insights to improve research assessment.

The authors began to investigate the impact of research at the CEI by considering seven key activities performed by academic researchers: conducting research, scientific publishing, commercialisation (e.g. creating new firms, patents and products), educating, networking, providing infrastructure (the tools that facilitate research, such as instruments and methods), and providing explicit guidance (e.g. policy advice).

To assess the value of these activities, the authors analysed how they relate to seven 'functions': influence on the direction of search (attracting organisations to enter a technological field, or guidance within a field), legitimation (social acceptance and compliance with institutions), market formation, entrepreneurial experimentation (e.g. testing new technologies), resource mobilisation (including human and financial capital), knowledge development and diffusion, and social capital development (development of social cohesion and common understanding).

Source: Jacobsson, S., Vico, E. & Hellsmark, H. (2014). The many ways of academic researchers: How is science made useful? *Science and Public Policy*, 41(5), pp.641-657. DOI: 10.1093/scipol/sct088.

The authors assessed the relationship between the activities and functions through case studies underpinned by interviews with CEI professors, and case studies' beneficiaries, prior evaluations and a patent analysis. This enabled them to capture the ways in which science creates value for society.

The results showed that all functions were influenced by academic activities. For example, conducting research had a direct impact on knowledge development and diffusion, resource mobilisation, entrepreneurial experimentation and influence of the direction of research. However, other traditionally less prominent activities such as networking also generated significant impacts.

The authors say that the focus on the direct impacts of publishing and commercialisation are inadequate for evaluating the benefits of science. To fully understand how science is made useful, it is important to map all activities and their impacts. The researchers also say assessments should reflect a wider range of impacts, going beyond simply counting the number of patents and spin-off companies.

They recommend that four key activities — networking, providing infrastructure, providing explicit guidance and educating — be considered by future assessments. They say networking is critical to making science useful by maintaining dialogue with external stakeholders. To measure this, the researchers suggest recording the number of 'dialogue partners'. Providing infrastructure could be measured by contributions to standards or the provision of methods; while providing explicit guidance can be evaluated by involvement in non-academic boards, presentations and media appearances. Finally, educating could be measured via numbers of graduated PhD and MSc students and engagement in professional education. Together, these indicators provide a more comprehensive reflection of the value of academic research.

"They recommend that four key activities — networking, providing infrastructure, providing explicit guidance and educating — be considered by future assessments."

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Changing research assessments could encourage knowledge dissemination

Research assessments should focus more on engagement processes and less on impacts and outcomes, a new study suggests. The authors examined researchers' intended impacts and motivational factors, and stated that a change in research evaluation methods, together with better direction from university managers, could help incentivise knowledge exchange and engagement between departments and non-academic entities.

"The researchers suggest that the current focus of research assessments on economic-based impacts diverts from incentivising the actual processes of engagement and collaboration which lead to knowledge exchange, and also increases the likelihood of impact criteria being achieved."

Increasing the benefits to society of public-funded research is a key aim of the Higher Education Funding Council of England (HEFCE), and a focus on knowledge exchange is an emerging priority of research worldwide. Funding bodies in the UK justify the monies they allocate to research projects using impact-based assessments — which generally have a strong economic imperative. However, the authors argue that the current emphasis of these types of assessment is of contested value, and argue that they do not provide sufficient incentives or guidance for future research.

The authors collated individual, academic and institutional perspectives on the impacts of university research by drawing on responses from two previous studies conducted in nine British universities. One study was a quantitative survey of 711 academics regarding their perceptions of the impact of their research, and the other involved 50 semi-structured interviews of academic staff, university administration and government personnel to gain perspectives on the value of university research.

The authors found that, in responses from a variety of different disciplines including medicine, science, arts and humanities, there was a wide variety in the intended impacts of their research but significant similarity in researcher's primary motivations.

In terms of intended impacts, although 'contribution to knowledge' and 'educational development' were highly rated across disciplines, certain impacts were highlighted by specialised disciplines – for example, 'informing public policy' was highly rated as an intended impact by social scientists, economists and lawyers, and 'cultural development or enrichment' by those in humanities and social science. One interesting cross-disciplinary result was in response to 'contribution to economy' — although less than 10% overall noted this as a primary impact of their research, around 50% regarded it a secondary impact.

In comparison, when asked about personal motivations for pursuing research, the responses were generally more unified across disciplines and institutions, the most important being 'making a contribution to scientific/academic knowledge' and 'intellectual curiosity or personal interest in the subject', with 86.9% rating both statements as highly important. Other motivational aspects that were rated as highly or moderately important by a significant number of respondents were 'boosting the status of your institution' and 'advancement of your career'. Additionally, respondents rated achieving impacts that were 'valued highly by their immediate peers' higher than impacts as valued by criteria that may lead to individual promotions and the Research Excellence Framework (REF).

Source: Upton, S., Vallance, P., Goddard, J. (2014). From outcomes to process: evidence for a new approach to research impact assessment. *Research Evaluation* 23: 352 – 365. DOI:10.1093/reseval/rvu021. http://rev.oxfordjournals.org/content/23/4/352

Evidence of research impacts currently accounts for 20% of the REF assessment, with a strong emphasis on economic impacts. The UK's Arts and Humanities Research Council's criteria has a different approach, which specifies that research needs to engage with policymakers 'in a systematic and active way'. The researchers suggest that the current focus of research assessments on economic-based impacts diverts from incentivising the actual processes of engagement and collaboration which lead to knowledge exchange, and also increases the likelihood of impact criteria being achieved. The authors state that while universities maintain a degree of independence, and therefore responsibility in this area, the focus of government policy on research assessments needs to change to better reward and allow time for engagement, collaboration and knowledge exchange activities.

"...while universities maintain a degree of independence, and therefore responsibility in this area, the focus of government policy on research assessments needs to change to better reward and allow time for engagement, collaboration and knowledge exchange activities."

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Creating 'buzz' for impact: Twitter and new media science communication

As the media environment changes, the way scientists communicate their work must also evolve. This study explored the effect of public communication on the scientific 'impact' of America's most highly cited nanotechnology researchers. It provides the first evidence that outreach activities, such as speaking to journalists and being mentioned on Twitter, can increase a scientist's impact.

"This key finding of this paper – that public communication can contribute to scientific impact in a measurable way – may cause scientists, who have traditionally been reluctant to take part in public communication due to academic demands, to think again."

Traditional forms of journalism are in decline, gradually being overshadowed by online media platforms. This change is affecting all forms of communication; science journalism too has shifted from traditional to online platforms.

Alongside changes to the media environment, the increasing number of specialisms within scientific research, the necessity for scientists to communicate beyond the 'ivory tower', and the growing demand for impact value in science means the way scientists communicate their work must change.

Some scientists assume that public communication of their work has little to offer, and may even be harmful to their credibility. For those that do communicate their work, this often involves little more than a press release; only a minority are actively engaged in communicating their work through popular media outlets. So, are many scientists missing out? Could scientists increase their impact by more actively engaging in public communication?

This study investigated these questions using a sample of highly cited US scientists working in nanotechnology. The authors analysed their communication activities in order to determine how different forms of outreach are related to scientific impact.

Authors of the most cited nanotechnology publications indexed in the Web of Science database in 2008 and 2009 were sampled. They were each sent a survey, which asked about their interactions with journalists and the public and how often they blogged. Alongside the survey results, cases in which their research was mentioned on Twitter were recorded.

The authors of the study measured the scientific impact of the final sample of 241 scientists using the 'h-index', an indicator which uses a scientist's most cited papers and the number of citations they have received overall to quantify scientific impact (and which works properly only for comparing scientists in the same field).

The results showed that, while most of the difference in impact could be accounted for by demographics and professional status, public communication behaviours were also important. For example, scientists who had more interactions with reporters had a greater scientific impact than those with fewer interactions.

Source: Liang, X., Su, L., Yeo, S., Scheufele, D.A, Brossard, D., Xenos, M., Nealey, P., Corley, E. A. (2014). Building Buzz: (Scientists) Communicating Science in New Media Environments. *Journalism & Mass Communication Quarterly*, 91(4), pp.772-791. DOI: 10.1177/1077699014550092

Scientists whose research was mentioned on Twitter also had significantly higher h-indices than peers whose research was not mentioned. Furthermore, the h-indices of scientists who interacted with non-scientists were higher if they were also mentioned on Twitter. In other words, being mentioned on Twitter appears to amplify the effect these interactions have on scientific impact.

This key finding of this paper — that public communication can contribute to scientific impact in a measurable way — may cause scientists, who have traditionally been reluctant to take part in public communication due to academic demands, to think again.

The finding that online 'buzz' about research — which may come from Twitter activity — enhances the impact of communicating through traditional outlets is also significant. The authors suggest that social media could supplement traditional approaches to measuring the impact of academic work.

Whether scientists decide to engage through new forms of media or not, there is no doubt that they are transforming science communication. The boundaries that have traditionally separated scientists, journalists and the public are becoming blurred, and scientists should adapt to this new landscape in order for their work to be understood, and ultimately to have meaningful impact for society.

"Scientists whose research was mentioned on Twitter also had significantly higher h-indices than peers whose research was not mentioned… In other words, being mentioned on Twitter appears to amplify the effect these interactions have on scientific impact."

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Read more about: Climate change and energy, Environmental information services

Internet tools for research dissemination: a climate change case study

Modern technologies have provided new ways for communities to engage with climate change. This study investigated the role of Internet-based tools in disseminating the findings of a climate change research project in Canada and provides insights on how best to use the Internet to communicate the outcomes of scientific research.

"The project aimed to identify innovative municipal approaches to climate action and record best practices, but also to trial new methods for knowledge mobilisation and the dissemination of research outcomes."

Climate change will affect communities and societies across the globe. Responding to this challenge requires coordination between nations, governments and sectors. On a smaller scale, it requires collaboration between researchers, local governments and communities — to share knowledge about climate change and the actions that can help mitigate it.

Online technologies offer new ways for this knowledge to be shared, and for the public to engage with climate change discourse. This study explored how new communication tools can be used to share knowledge on climate change and to encourage mitigation action, using the Canadian research project Climate Change Challenge (MC3). This two-year research project studied community-level climate change innovations in British Columbia. The project completed in June 2013 with the publication of an agenda for decision makers.

The project aimed to identify innovative municipal approaches to climate action and record best practices, but also to trial new methods for knowledge mobilisation and the dissemination of research outcomes. There was a heavy emphasis on electronic communication, which was used to circulate information to geographically dispersed communities in Canada and to build partnerships between scientists and practitioners. This information was also available on public websites.

Five key communication channels were used in the project: an online case study library; e-Dialogues (real-time, text-based communication between researchers and practitioners, in which the public could provide comments and questions) and LiveChats (online instant messaging forums); social media; peer-to-peer learning exchanges; and traditional dissemination (e.g. peer-reviewed journal articles). Aside from the last, each of the channels had a specific internet-based delivery method, all of which could be linked to optimise engagement. For example, social media platforms such as Twitter were used to draw attention to e-Dialogues and LiveChats. The authors investigated how effectively these different communication tools were used to disseminate the project's outcomes by measuring engagement, using metrics such as website traffic and views of case studies, videos and Facebook posts.

Their evaluation revealed several important insights. In particular, they found that building online presence and awareness of a research project is key to engagement, in a similar way to 'brand building' for businesses.

Source: Newell, R. & Dale, A. (2015). Meeting the Climate Change Challenge (MC3): The Role of the Internet in Climate Change Research Dissemination and Knowledge Mobilization. *Environmental Communication*, 9(2), pp.208-227.
DOI: 10.1080/17524032.2014.993412.

The researchers also found differences between active and passive online audience engagement. Public audiences were more inclined to 'spectate' than actively engage in dialogue. This was evidenced by the fact that e-Dialogues, which consist of expert panel discussions, attracted more participants than LiveChats, which are driven by audience participation. The authors suggest the lack of public dialogue may be due to a preference to 'learn from the experts' rather than engage actively in discourse, but say this needs further research.

The type of media used was also found to influence engagement. For example, Facebook data showed that the format of the content presented influenced the number of people who viewed the post. While the mention of climate change did not impact viewership, the insertion of an image did which suggests that appealing visuals can attract audiences on the Facebook platform.

Overall, the authors say researchers wishing to effectively communicate their findings should:

- Establish a web presence
- Think about how the public likes to engage with their field of science
- Consider how practitioners (e.g. policymakers) use media
- Be aware that different media types attract different audiences

The key message is that a project should not cease all activity when the research is completed. It is important to account for the continued and sustainable building of audiences for the outcomes of the research and explore creative methods of disseminating findings. The authors suggest this could also help to reduce the time lag between the publication of results and their use by decision makers.

While this study focused on climate change, its findings have implications beyond this particular issue and for communication of research outcomes generally.

"The key message is that a project should not cease all activity when the research is completed. It is important to account for the continued and sustainable building of audiences for the outcomes of the research and explore creative methods of disseminating findings."

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Further reading

You may also be interested in reading the following publications from Science for Environment Policy.

News Alert articles

Urban planners' views on the role of scientific information in decision-making [April 2015]

Simply supplying more scientific information on the environment may not be enough to persuade urban planners to give greater consideration to the environment, suggests new research. The Dutch study suggests that environmental values also need to be made more important to municipal decision makers.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/urban_planners_views_on_role_of_scientific_information_in_decision_making_412na1_en.pdf

Five principles to guide knowledge exchange in environmental management [November 2014]

Effective 'knowledge exchange' — the process of producing, sharing, understanding and using knowledge — is vital to good environmental management. New research has uncovered five principles for this process which could help researchers, decision makers and other parties work together to better manage environmental change.

http://ec.europa.eu/environment/integration/research/newsalert/pdf/five_principles_guide_knowledge_exchange_environmental_management_393na4_en.pdf

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