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Abstract

Many plea for a better integration of social sciences in energy research, which would imply more comprehensive interdisciplinary energy research. We argue that in order to achieve this, institutional barriers and research challenges need to be recognised and addressed. We identify six challenges and barriers, and provide recommendations for working towards solutions. We conclude that to engage in interdisciplinary research implies extra costs and fewer rewards for all researchers, particularly early and mid-career academics. We propose a new conceptualisation of practices and incentive structures among academic institutions, funding agencies, and publication outlets, and urge all energy researchers to join this debate.

Keywords: interdisciplinary energy research, science policy, university structures, publication process, research costs and rewards, early and mid-career academics

1. Introduction

Interdisciplinary research is needed to solve complex societal problems (Van Rijnsoever and Hessels, 2011). In this paper, we define interdisciplinary research as the synthesis of two or more disciplines, leading to the establishment of a new level of discourse and integration of knowledge. Conceptualized this way, interdisciplinary research differs from multidisciplinary and transdisciplinary research (Klein, 1990). Multidisciplinary research is defined as a process for providing a juxtaposition of disciplines that is additive, not integrative; the disciplinary perspectives are not changed, only contrasted (Klein, 1990). Transdisciplinary research can be

defined as a holistic approach that subordinates disciplines, looking at the dynamics of whole systems (Klein, 1990). Although multidisciplinary and transdisciplinary research are undoubtedly useful and needed to solve complex societal problems as well (Klein, 2008; Spreng, 2014), we focus on interdisciplinary research, along with its unique challenges and barriers.

Energy research is an exemplary interdisciplinary domain that integrates across many different disciplines, including but not limited to engineering, environmental sciences, computer sciences, mathematics, geoscience, economics, anthropology, business, and psychology (for a complete overview, see Sovacool, 2014b). Following our definition, the collaboration between two or more of these disciplines that establishes a new level of discourse, and integrates knowledge across the disciplines to address energy challenges, would constitute interdisciplinary energy research.

Energy research includes many technical challenges, and historically, many technical disciplines have worked on them. However, societal issues are also integral to energy research, and hence social sciences can contribute significantly (Rochlin, 2014; Ryan et al., 2014). This contribution relates to three main areas. Firstly, social sciences illuminate the factors that explain why consumers engage in energy behaviour and how energy behaviour may be changed, related to both when and how much energy is used. Secondly, they inform the development and evaluation of the effectiveness of interventions intended to change consumers' energy behaviour. And finally, they shed light on the factors that underlie public support for energy policies, technologies and infrastructure. These contributions go beyond “modelling” exercises, which are often used to capture energy problems (Jefferson, 2014). Social sciences can reveal important “errors” and “irregularities” in these models, and challenge underlying assumptions of other disciplines. The complex puzzle of building a sustainable and reliable energy system for the

future cannot be solved without consideration of these crucial components.

Despite their central role in developing effective energy technologies, programs, and policies, social sciences are still hugely underutilised in energy research (Felt, 2014; Sovacool, 2014a, b; Sovacool et al., 2015). Hence, a better integration of social sciences in energy research is needed, which is acknowledged by a variety of audiences including social scientists (Felt, 2014; Schmidt and Weigt, 2015; Sintov and Schultz, 2015; Sovacool, 2014a, b; Steg et al., 2015; Stern, 2014), engineers (iiESI, 2015), funding agencies (Winskel, 2014) and universities (National Academies, 2005). While prior work has explored similar topics (Rochlin, 2014; Ryan et al., 2014; Jefferson, 2014; Sovacool et al., 2014b), in this paper, we organize our ideas around challenging three major systems to make changes in order to foster the inclusion of social sciences in interdisciplinary energy research, particularly for early career scholars.

We are both environmental psychologists by training, and at the time this article was written, we both had joint appointments in (1) engineering schools and (2) business and public policy schools, respectively, to do exactly that: integrate social sciences in energy research¹. Whilst joint appointments like ours are part of an upward trend that goes beyond recognizing the importance of interdisciplinary energy research to stimulating it (National Academies, 2005), we have grappled with several institutional challenges and barriers that still hinder its success. We argue that before “true” interdisciplinary energy research can be realised, that is, the collaboration between different disciplines which leads to knowledge integration, such challenges and barriers need to be recognised and addressed. We identify six of the most important barriers and challenges, some of which are intertwined with more general issues in academia and/or apply to interdisciplinary research(ers) in general, but all of which are

¹ The second author has since accepted a new position in an interdisciplinary department at another institution, partly because of some reasons explained in this paper.

particularly relevant for interdisciplinary energy research(ers). We provide suggestions for working towards solutions.

2. Challenges, barriers and recommendations for interdisciplinary energy research

2.1 Insufficient knowledge and skills hinder successful interdisciplinary collaboration.

If future energy researchers do not understand the full context of the subject area, they are not likely to grasp the problems, and thus the solutions to this challenging research space. Additionally, as the integration of knowledge is key in our definition of interdisciplinary (energy) research, to maximise success, researchers need to acquire the necessary skills to do so (Shapiro et al., 2007). Therefore, training in how to conduct interdisciplinary research is much needed, and should start early to properly equip academics. Training should be scientifically rigorous and focus on mutual understanding of methodologies, (assumptions underlying) research traditions, goals and outcomes (Rynes et al., 2001). To achieve this, formal training can be used to increase knowledge about different angles of relevant problems and include a solid overview of technical challenges, (financial) risk analyses, demand side management and the role of markets and consumers. In fact, training programs that are centred around tackling specific problems to guide learning and inquiry, rather than around core components of a given discipline, have been suggested previously to reach similar educational outcomes (Sovacool, 2015). In addition, training “on the job” can aid in the development of other skills (e.g., communication with other disciplines, industry partners and policy makers). Integrating graduate students and postdocs in all aspects of interdisciplinary collaborations can aid in the latter (Cummings, 2005; Van Rijnsoever and Hessels, 2011).

It is important to acknowledge that one cannot become “interdisciplinary”, as all who engage

in interdisciplinary research need to have their own disciplinary expertise. After all, how can a researcher without expertise in a given subject matter ever succeed in the synthesis needed to establish a new level of discourse and integrate knowledge? Hence, it is important that all researchers are experts in their own unique areas—interdisciplinary training should be seen as another layer woven into training to acquire additional skills.

Recommendation: Interdisciplinary training needs to start early and focus on cross-cutting knowledge and skills whilst also allowing individuals to develop their own expertise.

2.2 Limited funding is available for interdisciplinary research and not proportionally equally distributed over disciplines.

Obtaining funding for interdisciplinary research can be a major challenge, as funding schemes often focus on disciplinary areas in silos, such as biological sciences, geosciences, or economic and social sciences, rather than on crossovers between them. If interdisciplinary energy research is funded, the traditional distinction between Science, Technology, Engineering and Mathematics (STEM) research and social sciences, which is often strictly kept by funding bodies, blocks the integration of social sciences in energy research (Felt, 2014; Sovacool, 2014a, b). Moreover, Sovacool et al. (2015) argue that social sciences suffer from “disciplinary chauvinism”, implying that they are treated as secondary and peripheral to STEM topics.

Although STEM research can justifiably require more funding than social sciences due to the nature of the work (e.g., equipment, field work, lab facilities), social scientists in interdisciplinary projects are often relatively under-funded compared to STEM researchers. This can limit the time, resources, and hence ideas that social scientists are able to contribute, thereby limiting knowledge integration. For instance, in the United States (U.S.), the National Science Foundation (NSF) is organised into “directorates” representing broad disciplinary categories;

since 2000, the Social, Behavioural, and Economic sciences (SBE) directorate has had the smallest budget of all NSF science directorates (AAAS, 2015), ranging from 3.3-4.1% of the total budget, whereas other directorates such as engineering have received twice to three times that amount. However, half of projects in SBE's portfolio were co-funded by other NSF directorates from 2001-2011 (Nichols, 2014), suggesting a desire to collaborate between social scientists and researchers from other disciplines, and the necessity of co-funding to enable such work. Similarly, the U.S. Department of Energy allocated an estimated 35 times more of its budget to research on hardware and infrastructure than it did to consumer behaviour and energy efficiency research (Gaffigan, 2008). Such funding priorities do not allow for perspectives from the broad range of social sciences to be brought to bear on the impacts of energy policies and innovations, and must be re-envisioned so that social sciences can become better integrated in energy research. Funding schemes should foster strategies that improve integration of *all* relevant disciplines in order to give energy research a chance to reach its full potential. This should be done at all levels of funding - (inter)national, local, and university - to ensure that academics in all stages of their career can build on this. *Recommendation: Funding schemes should stimulate interdisciplinary energy research that integrates social sciences.*

2.3 Funding evaluation criteria are not fit for measuring scientifically rigorous interdisciplinary research.

Tackling the challenge of reviewing interdisciplinary energy research proposals is not an easy task for funding bodies (Nightingale and Scott, 2007; Winskel, 2014). In contrast to mono-disciplinary proposals, reviewers are usually not experts on all proposal aspects. Instead, the evaluation of interdisciplinary energy research proposals tends to include experts from the involved disciplines, but lack experts in their linkage and integration (i.e., synthesis of

knowledge). Perhaps to aid in this challenge, “proxy” evaluation criteria are becoming increasingly common, which may result in de-prioritising scientific rigour (Nightingale and Scott, 2007). Among them is the extent to which proposals reflect “interdisciplinarity”, which usually implies that two or more disciplines are listed. However, this can be a surface-level checkbox, and what is often overlooked is “the establishment of a new level of discourse and integration of knowledge”, which we argue is the crucial part of interdisciplinary research. To illustrate, an engineer and an anthropologist may collaborate, and receive funding on this basis. However, anthropology may operate as an “add on”, without being truly integrated in the project, and the research itself may not be scientifically rigorous. Consequently, it would not be interdisciplinary research, and we argue such work should not be funded.

Similarly, funding bodies place increasing importance on “societal impact” as another common evaluation criterion. Prominent examples are the United States NSF Broader Impacts criterion and Research Excellence Framework in the UK (Martin, 2011). Although societal impact is undoubtedly an important outcome of interdisciplinary research, it is difficult to assess, and the implications of weighting this more heavily in evaluation processes has been questioned (Nightingale and Scott, 2007; Stuart, 2015). As a result, proposals tend to be funded under the banner of interdisciplinarity or social impact that do not significantly advance knowledge, nor reflect “true” disciplinary integration. This can lead to a lower standard for interdisciplinary research proposals receiving funding, with all sorts of negative side-effects.

The standards for funding interdisciplinary (energy) research must be transformed. We advocate for a renewed focus on scientific rigour and evidence of true integration of knowledge. This includes the process of different disciplines learning from and teaching each other and adapting standard approaches in order to form new perspectives, which requires collaborations

and communication from the very beginning of the development of research ideas. To stimulate such research, calls for energy research funding should be problem-oriented instead of technology-centered (Sovacool, 2015; Stern et al., 2016). *Recommendation: Interdisciplinary proposals should be evaluated based on scientific rigour, the establishment of a new level of discourse, and true integration of knowledge.*

2.4 Publication processes favour mono-disciplinary research in the short term.

Publishing in highly ranked outlets can be a challenge for all academics. However, this hurdle is even higher for interdisciplinary researchers, as journals are often organised along mono-disciplinary structures. Not many journals accept or value interdisciplinary publications and if they do, they struggle to evaluate them (Lee, 2006). This is illustrated in journal rankings, which suppresses interdisciplinary research (Rafols et al., 2012) and citation impact in the first 3 years after publication (Van Noorden, 2015). There are some journals that aim to change this, for example “Energy Policy” and “Energy Research & Social Sciences”, which publish high quality interdisciplinary energy research, and simultaneously aim to rise in the journal rankings.

Interestingly, in the long-term, citation impact of interdisciplinary publications increases (Van Noorden, 2015). Thus, although there are more benefits of investing in interdisciplinary papers in the long term, the short-term costs are high. Assuming that the value of science extends beyond short term journal impact factors, long term impact should be captured in existing impact factors, journal rankings and citations too, which are currently among the main criteria for evaluating both publications and researchers alike.

Whether one agrees with the currently used criteria to evaluate academics or not is a debate beyond the scope of this paper. However, we plea for revised publication processes in accordance with the recommendation that follows. *Recommendation: The publishing enterprise*

should focus more on academic rigour, interdisciplinary contribution (i.e., establishing a new level of discourse and integration of knowledge), and long term impact.

2.5 Academic promotion and tenure processes favour mono-disciplinary research.

Interdisciplinary research is undervalued within the academic system, which is reflected in the daily life of individual researchers. Many academics feel a tension between contributing to social problems by engaging in interdisciplinary research and their career prospects (Rhoten and Parker, 2004). Without downplaying the struggles that all academics have to get through promotion and tenure processes, interdisciplinary researchers experience additional tension, caused by different standards and common practices used to evaluate researchers' output and contribution. For example, the type of publications that are valued most (e.g., journal papers, conference proceedings, books), the number (e.g., single authorship common or not) and order of authors (e.g., role of last author) varies across disciplines. While such criteria may stem from noble values of fairness and desires to objectively compare researchers, it amounts to a rather rigid system, one in which interdisciplinary work has a hard time finding its place. Such systems are not set up to compare research output across disciplines, so interdisciplinary researchers are often evaluated based on the standards of a single discipline, typically the tenure-granting academic unit. This helps explain why the number of interdisciplinary publications lags behind (Xu et al., 2016), as a typical academic career benefits from a series of publication within certain types of publications in one discipline rather than from interdisciplinary publications (in lower ranked journals, see #4). *Recommendation: Evaluation criteria of researchers' output, contribution and quality should be comparable across disciplines rather than based on unique standards of mono-disciplines.*

2.6 University-level systems are not fully adapted to cultivate interdisciplinary

research(ers).

Universities increasingly acknowledge the need for interdisciplinary research, partly due to pressure by governments and research councils (and industry which has become increasingly present in research councils) who demand a larger contribution to societal problems (Henkel, 2005). As a result, an increasing number of joint training programmes, research projects and appointments between departments and institutions is observed (National Academies, 2005). However, not all universities are fully adapted to this yet. These positions often come with double duties in terms of securing funding, producing publications, teaching, supervision and engaging in service activities of the “home” department as well as the secondary department (on the upside, there are also double the colleagues and holiday festivities). Also, home departments may not recognise all activities integral to interdisciplinary research as valuable (National Academies, 2005), such as courses in other programs or departments, field work, or attending conferences outside the “home” field (Hoffman, 2014). Again, this effectively raises costs and reduces rewards for interdisciplinary research in academia, creating particularly high obstacles for early-career scholars. *Recommendation: Research employee evaluation criteria should be made common to align interdisciplinary activities with expectations of departments and universities.*

3 Early and mid-career interdisciplinary energy researchers

The research challenges and institutional barriers discussed above apply to all interdisciplinary (energy) researchers. However, our analyses indicate that in comparison to those focusing on a mono-disciplinary career path, early and mid-career energy researchers suffer most from the severe extra costs and fewer rewards when choosing to engage in

interdisciplinary research. They are often on fixed-term contracts or tenure-track positions, which means that they are usually evaluated on short term successes and mono-disciplinary standards. It is no wonder that many academics hesitate to pursue an interdisciplinary research career (Rhoten and Parker, 2004). This is particularly problematic as early and mid-career academics are much needed in interdisciplinary research to accelerate its impact and reach its full potential.

4 Conclusion

What does this all mean? Should we quit our jobs? No! Interdisciplinary energy research, in which social sciences play a mature role, is much needed to create a sustainable, secure and affordable energy future. There is however every reason to assume that well-intentioned academics choose to focus on one discipline and follow a career path that is currently supported for career reasons, rather than attempting to pioneer the bumpier route of interdisciplinary research. We urge universities, publishers, funding agencies other institutions, as well as individual researchers to reconsider their priorities: if interdisciplinary energy research is valuable, then important changes in systems are needed. In Figure 1 we sum up the most important focus areas for such changes in three key systems. First, in the science policy system, including funding bodies, more funding should become available for interdisciplinary energy research, and that funding should include all relevant disciplines, such as social sciences. To stimulate such research, calls for energy research funding should be problem-oriented instead of technology-centered (Sovacool, 2015; Stern et al., 2016). Also, when evaluating research proposals, the main evaluation criterion should be scientific rigour, rather than proxies that are currently often used; changes in review panel composition are also indicated to represent not

only disciplinary expertise but also the synthesis between disciplines, which is currently often neglected.

Second, with respect to the publication process, the publication of interdisciplinary research needs to be further stimulated. At the moment, mono-disciplinary papers are heavily favoured, even though the long term-impact of interdisciplinary research papers is higher. Hence, a shift from emphasis on short-term to long-term impact is needed, to increase the value of interdisciplinary research publications. The publication of interdisciplinary research papers should be stimulated for example via special issues.

Last but not least, universities and the academic community need to reconsider their values and structures. Current evaluation and promotion criteria in academia are suited to mono-disciplinary structures. To encourage interdisciplinary research, this has to change: interdisciplinary research should be incentivised rather than punished, and interdisciplinary researchers should be rewarded rather than pay high career costs. To achieve this, employee evaluation criteria must be redefined and university and academic structures need to change. Finally, interdisciplinary training needs to be provided from an early stage, hence universities should develop interdisciplinary training programs and create opportunities to engage in interdisciplinary research for students and young researchers.

At the centre of Figure 1, where the three areas overlap, all systems and mechanisms should collaborate to create the ultimate support system for interdisciplinary (energy) research. For example, high standard interdisciplinary funding would be promoted by funders (science policy), the products of that research should be welcomed in the publication process and academic evaluations in the university system (universities). Simultaneously, problem-oriented education and training (universities) should support the high quality interdisciplinary research underlying

this mechanism.

Do not get us wrong. We do not intend this as a plea for more funding or respect for the work that we do, nor do we argue that interdisciplinary research should replace mono-disciplinary research. Rather, we plea for a system make-over, one which challenges, promotes and supports high quality interdisciplinary (energy) research to contribute to complex societal problems, alongside much valued mono-disciplinary work. To do this, a serious re-think of norms, values, evaluation criteria, rankings, and impact factors is needed with a stronger focus on scientific rigour to aid interdisciplinary energy research in reaching its full potential. Simultaneously, we encourage all interdisciplinary energy researchers to get actively engaged in this debate on all levels and strive for change.

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Figure 1. Overview of focus areas to encourage interdisciplinary energy research