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OPINION

Open science and the climate crisis

Michael J. Fell*, Nicole E. Watson, Gesche Huebner

Bartlett School of Environment, Energy and Resources, University College London, London, United Kingdom

* michael.fell@ucl.ac.uk

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Introduction

In 2009, the climate research community was rocked by the Climategate controversy, an email leak that allegedly provided evidence of data manipulation [1]. While that allegation was shown to be unsubstantiated [2], it focused the community's attention on the importance of transparency in generating findings that are both robust, and seen to be robust. Data errors [3] and challenges in reproducing findings [4] have prompted similar self-reflection in the fields of economics and psychology respectively. Energy research has so far avoided a similar crisis of trust. But for how long, and at what cost?

Burning fossil fuels for energy is the main contributor to climate change [5]. Robust research is key to anticipating future energy demand trajectories, and how these might best be managed to minimise greenhouse gas (GHG) emissions. Sharing research, including data, can help others to conduct further research more efficiently and faster, which is of crucial importance in times of a climate crisis. But energy researchers have still not widely adopted the range of approaches used to maximise the transparency, reproducibility, quality, and accessibility of research (known as Open Science) that are now commonplace in other fields.

Open science involves making research processes, inputs, and outputs (such as method detail, data, and papers) as accessible and transparent as possible. Following their own crises, disciplines like psychology have increasingly recognised the value of open science tools and approaches. Research data are routinely shared in repositories. Preregistration is used to pre-specify hypotheses and analysis approaches, minimising the chance of practices like HARKing (hypothesising after results are known) and p-hacking (manipulating inclusion of variables in statistical tests to produce statistically significant findings). Reporting guidelines are employed to help ensure all relevant details of study methods are included, making it easier to evaluate conclusions, and spot biases and omissions. Rigour-enhancing practices including confirmatory tests, large sample sizes, preregistration and methodological transparency has been shown to create high reproducibility of findings [6]. Being transparent in these ways should also contribute to greater public trust in science, as work is open to greater scrutiny.

Challenges for energy research

Evidence on the use of Open Science in energy studies is scarce, but what there is suggests limited uptake of these approaches. For example, as a proportion, 2.7 times as many post-2019 papers mentioning randomised control trials (RCT) in "psychology" compared to "energy" as indexed on Scopus also make mention of the CONSORT guidelines for reporting of RCTs. For preregistration the difference is even more stark, with 25 times as many papers which mention experiments in psychology as in energy also mentioning preregistration. Our own informal survey work suggests little familiarity with, or use of, open science approaches. While by no

means conclusive, we certainly don't get the sense of open science entering the energy research culture in the same way as other fields.

Why could this be? In our previous work in this area [7], we suggest a range of possible contributing factors. One is the highly multidisciplinary nature of energy research, where disciplinary norms are likely to differ substantially. Another is the rapidly changing landscape. A topic like attitudes to electric vehicles is likely to differ more over years than, for example, people's perception of colour, meaning that issues such as reproducibility may be considered less relevant. There are also practical challenges. Real-world trials in energy are often very expensive, while the trials themselves are often context-specific, again making replication difficult compared to highly controlled lab-based studies.

These (and other) factors have contributed to a situation where open science approaches are not routinely taught in energy research and are often not requested by journal editors and reviewers, or funders. Even where researchers are aware of or required to engage, the costs of doing so are often perceived as outweighing the benefits. Funders, institutions and publishers could certainly do more to recognise researchers' efforts. However, we think there also needs to be wider awareness of existing and potential benefits of greater transparency, both personally for researchers and in supporting quicker, more effective climate action.

Benefits of open science approaches

An often-cited example of the open science overhead is the preparation of datasets for sharing. To be as widely useful as possible, data need to be FAIR–findable, accessible, interoperable, and reusable. This requires things like having useful metadata, and clear variable names for quantitative datasets, all of which take time. However, researchers who plan to share their data from the outset, and build this into their workflow, can minimise overhead while also producing datasets that they can understand when they return to them in the future. Publishing datasets and data papers can lead to citations [8] which, like it or not, often play into job and promotion decisions.

Beyond the personal benefits, data sharing can reduce the need for redundant research (by recollecting data that may already exist), improve the productivity of data collection (by letting the same data be used for extra purposes), and potentially unlock new climate solutions (such as through novel combinations of diverse datasets [9]). Additionally, few policymakers have access to academic journals behind paywalls, meaning that publishing open access can help make research available to decision makers. Open access publishing can also support scientific literacy in the wider population [10], playing an important role in tackling misinformation [11].

So what is to be done? We see potential for change both at the level of individual energy researcher, and in the broader research ecosystem. There are plenty of resources available to support researchers in adopting Open Science approaches. For example, AsPredicted.org makes preregistering studies easy, while the Equator Network lists reporting guidelines for a wide variety of study types. As well as adopting open science approaches themselves, researchers are often well-positioned to introduce them to others through teaching and student supervision.

More broadly, to encourage good practice, institutions should start to recognise open science approaches in their promotions and hiring procedures. Funders can both require the use of open science approaches, and acknowledge the need for funding to cover any additional time requirements. For example, UK Research and Innovation and the European Research Council now require all research publications acknowledging their funding to be published open access [12, 13]. Publishers can support options to share preprints and, at the very least, require statements on data availability.

In conclusion, instead of waiting for a crisis or scandal to spur action, energy research should work to quickly make it research more transparent and accessible. This is of urgent importance to deliver the research and solutions we need in the face of a climate emergency.

Author Contributions

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