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OPINION

Towards more impactful energy research: The salient role of social sciences and humanities

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Despite long-standing pleas for interdisciplinarity and a more significant role of social sciences and humanities [1], energy research (ER) largely remains the remit of hard sciences, such as climatology, physics, and engineering. Contributions of social sciences and humanities (SSH) are routinely separated and rarely considered in discussions about energy strategies. This is particularly problematic because citizens have a role to play in the decarbonization of energy systems through the pursuit of more localized and collective forms of renewable energy production, reduced and more efficient energy usage, and voting for necessary regulatory changes. More generally, social, political, and socio-technical changes will be needed at every scale to ensure a successful energy transition.

As "research focused on technological solutions is a crucial enabler for the energy transition but is not enough" [2], we invite scholars from diverse SSH fields,–including but not limited to geographers, historians, philosophers, psychologists, political scientists, linguists, public health experts, economists, sociologists, anthropologists, labor rights experts, experts on demographic change and many more– to intensify joint work on the energy transition. Towards this aim, we engaged with SSH energy researchers in Switzerland towards the promotion of both inter- and trans-disciplinary energy research and practice. As a result of this process and inspired by previous efforts to put forward an SSH research agenda [3], we propose the following five priority directions, which have transformational potential.

Language lies at the core of communication. At the same time, the choice of specific words and framings can influence what recipients understand and how they process information. It matters whether we speak of *energy production*, *energy supply*, *or energy services*. Words open frames that carry specific perspectives, values, and attitudes—of which we are frequently unaware. This is particularly relevant in the field of energy studies, which involves many cross-cutting perspectives and topics. In this vein, a better understanding of how language shapes perception, behavior, and practices is needed at different levels. Interdisciplinary research opens opportunities to uncover different understandings of seemingly unproblematic or technical issues towards more effective collaborations and deeper understanding. Language is also significant in transdisciplinary research regarding shared understandings between diverse societal actors, including the general public and its anthropological, psychological, and communication determinants of (in-)action. While linguists have provided evidence that language

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can be used as a tool to affect the framing of energy-related questions, perceptions, and related actions, the role, and potential of language in ER have not yet been systematically investigated, even less so from an inter- and transdisciplinary perspective [4]. This is only the first step to utilizing the full power of humanities as orientation and reflection sciences [5]. Hence, language and linguistics should have a prominent role in future ER projects.

The distributional impacts of the energy transition are central to the study of justice and public acceptance [2]. Changing energy systems and policies, along with climate change impacts, will not affect all people equally. However, questions related to the distributional effects of the energy transition have recently gained importance in scientific and public debates [6]. One example is the Swiss CO_2 law, rejected by the Swiss electorate in June 2021, where counter-arguments were centered around potential disproportional tax effects on society. Hence, especially for the political implementation of the energy transition and related policy measures, more insights into distributional effects and how to make the energy transition socially fair are crucial [7]. Alternative designs of the energy transition can have a differentiated social impact on different groups, such as income groups [8] or gender [9]. Thus, they can be ranked by justice criteria. Research including a broad range of SSH disciplines is needed to integrate modeling and economic perspectives to address the plurality of possible futures and achieve an equitable and sustainable energy transition [10].

Grappling with **complex realities**, such as co-diffusion and co-adoption of energy-related technologies and lifestyles [11], is perceived as a way forward as the energy transition is ultimately a social endeavor, marked by high complexity. This involves different social and political aspects such as public and elite acceptance, changing norms and expectations around what it means to live the good life, new socio-technical systems, and new regulatory and institutional settings, to name but a few. While SSH has contributed extensive research on energy systems and policies, it is necessary to integrate the different fields into a holistic perspective on the energy transition. Establishing an overarching framework that grapples with wider socio-technical and political dynamics helps to structure the research consistently and exploit its full potential– without delay. SSH-led ER allows the application of this framework to a wide range of other research priorities. It enables a more realistic, multifaceted analysis of today's and tomorrow's energy challenges.

Methods used jointly such as field experiments, public acceptance studies, SSH-informed agent-based modeling, living labs, and real decision-making settings can provide SSH-driven insights that are closer to reality, and thus more effective in acting on social change. Whereas many SSH studies rely on hypothetical measures [12], lack of context, and an over-emphasis on individual behavior change, novel interdisciplinary methods are emerging. For example, the combination of field experiments with living labs allows for the co-production of knowledge with diverse actors in everyday contexts, towards experimenting with change and increasing the external validity of the findings. Technological advances in information acquisition, such as mobile sensing approaches, enable more precise measurements as complementary to existing SSH approaches. Moreover, human-centered modeling approaches such as agent-based modeling can transfer SSH findings on individual decision-making and behavior from the individual level to the level of larger social systems [13]. These approaches further enable the analysis of dynamic behavior and social interactions across time. Incorporating the individual and system level in the analysis of SSH research is likely to foster exchange between SSH and other disciplines and between SSH and policymaking.

Threats and opportunities during accelerated energy crises and potential shortages require an SSH perspective. The current energy crisis has triggered discussions about topics that had been taken for granted, e.g., resilience and price predictability [14]. Grid-supplied electricity, for example, was available at low costs and at all times in many European countries. This

situation has tremendously changed due to the Russian war against Ukraine and other global developments, including climate change. Techno-economic modeling approaches can simulate the resilience of energy systems under these circumstances and the political, social, technical, and economic consequences of potential energy or power shortages or blackouts, with a possible new argument in favor of rooftop photovoltaics and energy communities. Bringing SSH into these discussions is necessary towards reinforcing the need to challenge existing systems–towards promoting sufficiency and the overall reduction of energy usage along with efficiency, for example. Scientific insights on how the population reacts to energy and other crises and how citizens perceive, e.g., the relationship between energy security and renewables, have significant political implications. How such crises are used to make the energy system reliable and to achieve climate goals might be a potential leverage point arising from these new challenges.

In summary, while SSH has much to contribute to energy research, there is a need to build bridges not solely between SSH and other approaches to ER. More work needs to be funded [15] to bring diverse social scientists on board if we are to take the climate crisis seriously as the pressing and central challenge of our times. The five priorities we have described can significantly improve the effectiveness of resulting ER policy propositions, as well as enable social change at different scales, from local to international. As the energy transition must be accomplished in a very short historical time, with inter-related crises, it requires a trans- and interdisciplinary effort drawing on historical lessons. Therefore, it is important that SSH energy research includes all relevant disciplines and actors–towards an SSH-led "all hands on deck" approach to energy and climate research.

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