INTRODUCTION

Critical perspectives in technology assessment: On the relevance of care for sustainability transformations

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Abstract · In the introduction to the Special topic, we highlight the importance of exploring concepts, approaches, and practices of care in order to give new impetus to technology assessment and to unlock the potential of such approaches for a socio-ecological transformation toward critical-emancipatory sustainability. The introduction also contains a brief description of each article.

Kritische Perspektiven in der Technikfolgenabschätzung: Zur Bedeutung von ‚Care' für Nachhaltigkeitstransformationen

Zusammenfassung · *In der Einleitung zum Special topic zeigen wir, wie wichtig die Auseinandersetzung mit Care-Konzepten, -Ansätzen und -Praktiken ist, um der Technikfolgenabschätzung neue Impulse zu geben und das Potenzial solcher Ansätze für eine sozial-ökologische Transformation in Richtung kritisch-emanzipatorischer Nachhaltigkeit zu erschließen. Die Einleitung enthält außerdem eine kurze Beschreibung der einzelnen Artikel.*

Keywords · *care, socio-ecological transformations, sustainability, technology*

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Objectives

We aim to showcase new research and experience related to care concepts, approaches, and practices that foster sustainability transformation in this Special topic of TATuP, thereby offering fresh perspectives for technology assessment (TA). Our intention is to discuss the empirical value of care in critically assessing the role of technologies and to explore its importance for the empirical analysis of technological innovations in sustainability transformations. Practical applications of care are therefore discussed in this context and examined with respect to how it can enrich current debates in TA. Our interest is to explore how the concept of care can extend beyond and enhance current debates and frameworks such as the precautionary principle. We address ways in which concepts of care can be used to inform technology policies, governance processes, and regulation related to digitalization, artificial intelligence, and other new and emerging technologies. In addition, its strengths and weaknesses, limits and opportunities are identified. This topic essentially explores how care can contribute to, and be enriched by, new perspectives to ultimately foster a more sustainable economy.

In this context, we focus on political initiatives for sustainability transformations, such as the green economy, the bioeconomy, and the circular economy. These initiatives have all been criticized for being too focused on economic growth and technological solutions (Gottschlich et al. 2014; Boyer et al. 2023; Eversberg et al. 2023; Geiter et al. 2025). However, despite the justified criticism of pure techno-fixes, some technologies do have the potential to advance transformation towards more sustainability. For example, urban transformation can benefit from

intelligent infrastructures to effectively coordinate various intersectoral transformation processes such as renewable mobility, electricity and heat generation.

Hence, this Special topic examines selected technologies that shape our society, while presenting a critique of technological solutionism. As the risks and impacts of existing and emerging technologies on society and nature are often uncertain, unknown, or controversial, their assessment with a focus on precaution and care becomes essential.

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To some extent, this has already been done in participatory TA, where expert assessments (Sauter 2005; Albrecht et al. 2017; Stirling et al. 2018; Reinermann et al. 2022), responsible research and innovation (Asveld et al. 2015; Felt 2018), and other risk assessment approaches in key sectors like energy, planning and infrastructure, or food and agriculture have already incorporated elements of it to varying degrees (Levin-Keitel et al. 2018; BfR 2019; Thompson 2020; CSPO 2021; Participedia 2024).

However, it has been argued that many of these approaches still operate within flawed and overly narrow technology and risk assessment frameworks that inadequately consider the complex societal and political contexts and their inherent uncertainties (Groves 2015; Garnett 2021; Whittingham and Wynberg 2021).

In order to more fully critically engage with conceptualizations and practices of care in TA of sustainability transformations, we have gathered contributions from different disciplines and research perspectives ranging from political science, sociology, political agroecology, environmental and agricultural engineering, innovation studies, science and technology studies.

As the state of research on this topic in German TA debates is rather limited and the reception of debates around concepts of care in this field has just started, we aim to broaden the international visibility of care approaches and further advance the debate in this field with this journal's Special topic.

State of research

Care approaches relevant to our topic have evolved in various debates and across disciplines. A care perspective, as developed in (feminist) science and technology studies, offers important insights for critically assessing innovations aimed at sustainability. The question which technological innovations advance socio-ecological transformations is of crucial importance. Existing work on the concept of care and technology policy highlights its potential to draw attention to issues often neglected in innovation theory or risk assessment, such as responsibility, relationality, contextuality, dependency, or power relations. This focus also brings attention to institutions that regulate and govern social or technological innovations, political processes, and economic practices (Groves 2015; Martin et al. 2015; Hackfort and Saave 2024). Scholars in this field have identified key features of a care perspective on technologies, particularly in assessing the risks and implications of biotechnology and genetic engineering (Preston and Wickson 2016; Puig de la Bellacasa 2011; Whittingham and Wynberg 2021). One example of this is the increasing control over food production and the marginalization of agroecological approaches as a consequence of genetic engineering in the agricultural industry (Curry 2002; Preston and Wickson 2016; Whittingham and Wynberg 2021).

Concepts of care advocate for including socio-economic, cultural, and political factors in risk assessment, such as the influence of economic interests of various actors and power dynamics. A care perspective involves a concept of risk that differs from a "consequentialist-based framework of assessment" (Whittingham and Wynberg 2021, p. 2) for technologies. While the latter is based on a positivist understanding of (natural) science with claims to objectivity and derives risks from technologies accordingly (proven negative effects of genetic engineering on human health or the environment), a care perspective criticizes this as too narrow. Feminist critiques of science have shown that the claim to objectivity is itself problematic, as every theory, experiment, and innovation is already based on human-made assumptions and ideas. Proponents emphasize that every discipline of knowledge production, including the natural sciences, is embedded in society and that scientific findings are therefore always influenced by social power structures. The category of gender plays a particularly important role here, as even the seemingly neutral perspective of natural scientists is often shaped by unconscious societal notions of gender and gender relations (Harding 1991).

Donna Haraway's concept of 'situated knowledge' (Haraway 1991), for instance, emphasizes that knowledge is always partial and situational and that assumptions must be made transparent. This requires negotiating different perspectives and including diverse actors. Doing so helps to avoid the exclusion of knowledge forms and thus achieve something akin to objectivity. Recent work using care as a lens to assess technologies aligns with this feminist critique of science. It highlights the legitimacy of

diverse forms of knowledge and challenges the existence of patriarchal, technocratic power structures in knowledge production and in political and decision-making spaces in innovation policy. The work advocates for a more democratic and inclusive process instead that reflects the diversity of voices, especially those of marginalized groups — "the multiplicity of scientific and academic voices but also the voices of the marginalized" (Whittingham and Wynberg 2021, p. 3). Further important approaches in this emerging field therefore include decolonial or degrowth perspectives to critique the "objectification of nature" (Arora and Van Dyck 2021, p. 254) traditionally upheld in Western modernity and the solutions arising from its paradigms (Puig de la Bellacasa 2011; McGreevy et al. 2022).

Another strand inspired by feminist democracy theory, which we find stimulating to explore, is the importance of care in the empirical analysis of technological innovations in sustainability transformations. This includes literature on care as a transformative principle for society, politics and the governance of society-nature relations (Fisher and Tronto 1990; Tronto 1993; Gottschlich et al. 2014; Gottschlich and Katz 2020). Particularly in the field of political ecology, the term refers to care work for future generations, for nature, for animals and plants, as well as their respective specificities and characteristics. It fundamentally embodies a critique of economic relationships that prioritize logics of growth and exploitation over social and ecological reproduction needs and the fulfillment of basic necessities. Concepts of care are aimed at a greater awareness of our relationship with nature. They thus provide ethical tools for a precautionary economic and life-sustaining technology policy to meet the challenges of justice and sustainability while going beyond existing debates and concepts on the precautionary principle (Gottschlich and Bellina 2017; Gottschlich and Katz 2020; Gottschlich and Hackfort 2022).

For example, a precautionary care approach to farming and food production considers, among other things, nature's own time, aims to preserve and improve soil fertility (Puig de la Bellacasa 2011), combines ecological and social justice issues, and applies the principle of care and precaution when assessing the use of new technologies such as genetic engineering or precision agriculture (Whittingham and Wynberg 2021; Hackfort and Saave 2024). Care-centered critical-emancipatory approaches direct attention to the socio-ecological transformation processes that must align with the political institutions, and production processes and lifestyles in industrial capitalism (Wichterich 2021). Such transformations can only succeed if social inequalities are addressed and overcome. Critical-emancipatory approaches to sustainability that places the concept of care at the core allow us to take into account these social dynamics (Gottschlich 2017; Gottschlich and Katz 2020; Anderson 2021). Here scholars refer to care in a broad sense "as a species activity that includes everything that we do to maintain, continue, and repair our 'world' so that we [and other earth others] can live in it as well as possible" (Fisher and Tronto 1990, p. 40, cit. in Tronto 1993, p. 103).

Contributions to this Special topic

The contributions in this Special topic explore concepts and practices of care that highlight and enable alternative imaginaries and politics of technologies and practices of TA in sustainability transformations. Taken together they need to be understood as an approximation, as a kind of test field in which the relationship between society, nature, and technology from different care perspectives are investigated using different questions and varying approaches to diverse themes.

The article 'Decolonizing technology assessment: Towards a radical transformation of the modern world' by Saurabh Arora and Barbara Van Dyck offers a conceptual approach to decolonizing TA in relation to agriculture. The authors highlight the persistence of colonial relations not just between nations, but critically between socio-material worlds that support different ways of being and knowing in agriculture and across agroecologies. The authors move beyond colonial relations of superiority and supremacy, control and domination, extraction and appropriation, which inform the modern world. Saurabh Arora and Barbara Van Dyck put forward the notion of radical care, which draws from feminist and indigenous movements. They advocate for decolonizing TA which involves providing support and solidarity for struggles aimed at confronting and dismantling colonial relations that sustain the concentration of power and privilege in modern societies. They support their conceptual proposals with brief examples from agriculture. Doing so, they seek not only to address and challenge patterns of power and privilege related to technologies and innovations that tend to harm (colonized) communities, but also to promote alternative ways of knowing supported by colonized peoples, whose life-sustaining practices have shaped multiple worlds. This care approach goes beyond the colonial dynamics between nations and cultures, emphasizing contemporary interactions with diverse worlds both during and after colonial rule, and encompassing perspectives from both the Global South and North. Arora and Van Dyck's article offers a widely overlooked approach by emphasizing a decolonial view of TA. With it they contribute to a better understanding of how TA can transcend precaution as techno-scientific pluralism and dismantle colonial relations both within and between societies.

Sarah Maria Schönbauer addresses in her article 'Careful handling of marine plastic litter: Technology assessment and care' waste as a core concern in today's societies. Using the example of marine plastic litter, which has dire effects on ocean ecosystems, she discusses how TA scholars can address the issue and explores care concepts for TA processes concerning waste. In the article, she illustrates how care concepts not only help to understand the complexity of waste but also the environments they affects, the regulatory processes involved, and the technical innovations that arise. Sarah Maria Schönbauer argues that focusing on environmental care in care reflection processes could assist TA practitioners in sensitizing TA practices not only towards concerns on different scales of world politics but also to emotional attach-

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ment, responsibility distribution and marginalization processes, core characteristics of care that open up "neglected experiences that create oppositional standpoints" (Puig de la Bellacasa 2011, p. 96).

Johanna Krings and Nora Weinberger in their contribution 'Technology or practices of care first?: Technology assessment in the tension between 'technology push' and managing socio-technological futures' underscore the crucial role of TA in balancing technological development with care principles. While TA has integrated care-based approaches, project outcomes reveal that these efforts are insufficient for fostering truly 'caring' societies. Technological solutions often lack alignment with the specific needs of users and the social contexts of care, creating significant tensions. The article advocates for a 'care-sensitive' TA that not only ensures technological robustness and adaptability but also facilitates continuous 'tinkering' to refine technologies within dynamic care settings. A reciprocal, context-aware approach benefits both caregivers and recipients, embedding technology into care practices rather than subordinating care to technological imperatives. Ultimately, such an approach promotes a more responsive, empathetic caregiving environment where technology finds its 'place'.

Corinna Peil's article 'Infrastructures of care: Ethics in everyday digital media use' presents a novel conceptualization of digital media as infrastructures of care, integrating care ethics to examine the role of maintenance and support in fostering sustainable and equitable digital environments. By examining challenges and user support relations within digital media use, it proposes policies that enhance technological sustainability and inclusivity, emphasizing the role of care in ensuring the reliability and functionality of digital infrastructures shifting our focus towards their sustainable maintenance and usage. Peil underscores Krings and Weinberger's position that a precautionary development of technology based on care can represent a continuous technological improvement of socio-ecological conditions through a reciprocal understanding of relationships with users. She argues that technological literacy is crucial, as we are surrounded by technological artefacts, especially in the Western world. These artefacts organize, structure, and also inform our societies as well as our everyday lives. For Peil, care becomes a political category, as there is a need for a policy of knowledge that focuses on the care and maintenance of technology.

Benedict Lang's article is titled ''Daseinsvorsorge' as a care-based principle of transformation: Perspective toward a caring development of sustainable cities'. He addresses smart cities that use sensors, data and applications to transform urban infrastructures towards sustainability. Critical scholarly examinations of the smart city have failed to integrate care. Based on empirical insights, he argues that 'öffentliche Daseinsvorsorge' (understood as public services essential for ensuring a basic quality of life) presents a guiding principle of urban statecraft that initiates responsible research and innovation based on care reflections. He explores the concept as a critical lens for evaluating transformation projects from a care perspective. Lang demonstrates that the literature on responsible research and innovation overlooks a discussion of what precautionary technology development truly entails, as well as the values associated with it. In addition, he proposes a normative framework that reflects the role of municipal administrations and their responsibilities towards citizens. He then argues for a care-oriented concept of 'öffentliche Daseinsvorsorge' – essential public services that ensure a basic quality of life – to evaluate and assess sustainability transformations and their technological implications beyond existing debates.

Care-centered critical-emancipatory approaches direct attention to the socio-ecological transformation processes that must align with the political institutions, and production processes and lifestyles in industrial capitalism.

To promote social-ecological transformation and a sustainable economy, Andrea Vetter pleads in her interview 'How to care about technology?' for instituting a 'moral code for technology' that is committed to the principle of care. Maintaining technical infrastructures and devices requires a lot of care, without which they would fall apart. To take on this care work, it is essential that people relate directly to technology and have the knowledge not only to use it but also maintain it.

Conclusion

The articles in this Special topic offer valuable insights into how incorporating a care perspective into technology assessment can facilitate social-ecological transformation. It is evident that, while care concepts are interpreted in various ways in practice, common elements in care approaches include a critique of power relations, the significance of relationships and an examination of who benefits from technology.

With all the contributions in this Special topic we hope to establish a care perspective on sustainable development that re-

search has insufficiently taken into consideration. A care perspective calls for the acknowledgement of uncertainty and complexity, and is based on the key principles of responsibility, relationality, contextuality, and dependency. It aims to broaden our understanding of technologies and their implications while widening our notion of (appropriate) solutions including non-technological or low-technology approaches to maintaining nature's reproductive capacity as key for sustainability. We firmly believe that any technological innovation, assessment, economic activity, or political governance that does not incorporate care as an intrinsic component will ultimately fail to achieve sustainable economies and societies.

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