Shaping energy landscapes sustainably – Extended Abstract

Proposal from the IP6-plattform project "Transforming energy landscapes" written by Danial Esmaeili, Paul Lehmann, Till Markus, Daniela Thrän; September 2023

Introduction

Both a fast transition of the energy system towards renewable energies (RE) and carbon dioxide removal from the atmosphere (CDR) are key to stay within the 2°C Paris target. While politics in Germany adopt and implement measures to accelerate the transition towards the net-zero goal, various conflicts can be expected from the related land requirement for both RE and CDR deployment. Land-use conflicts may arise due to trade-offs with other land uses, e.g., food production, disamenities for local residents, or adverse impacts on biodiversity. Conflicts may be related to the land's surface due to the installation of different RE infrastructures (wind and solar farms, biogas, power lines etc.) as well as its subsurface for the storage of CO_2. In addition, land use conflicts may arise domestically, but also abroad when RE is imported or removed CO_2 is exported. Hence, land is "*the pertinent issue and factor* in the process leading up to net zero (RE share in final energy consumption in 2022: 20 %). A particular challenge arises for biomass, which is faced with many expectations for RE provision and CDR, but also for substituting fossil carbon in plastics etc. The newly evolving energy landscapes put additional pressure on land and need to be developed and managed sustainably: RE and CDR facilities need to be directed to technically, economically, and socio-ecologically optimal locations.

Mission

Our mission is to develop and apply analytical and modelling tools with high spatial resolution as well as broad frameworks for sustainability assessment that support decision makers concerned with the energy transition in targeting a wide range of possible ecologic, social, and legal conflicts.

Previous energy system analyses largely neglect local conditions and requirements for sustainable use and the feasibility of new technologies. This is due to the fact that these analyses are spatially coarse and use incomplete evaluation frameworks for sustainability assessments. In response to these gaps, we are particularly interested in understanding how the spatial implications of RE and CDR are developing and will interact with expectations and preferences of regional stakeholders. These analyses qualify us to develop coherent solution approaches for sustainable energy landscapes and support the successful implementation of the energy transition. At UFZ we have the unique opportunity to combine a broad and cutting-edge expertise in land-use modelling with social and system science expertise in energy system and energy governance research.

Results / Products

To answer the envisioned research question, we focus on two central research challenges: (1) analyzing and assessing the location of RE plants in Germany (where are plants located, where should plants be located, which spatial trade-offs arise) and their potential for a sustainable energy transition and (2) exploring and the potential for implementation of CDR by bringing forward an analytical and legal framework for CDR landscapes. This has led us to the following products in the past:

(a) **A complete data set of all RE installations in Germany since 1990** (Manske, D., et al (2022)) is free available and **integrated in the interactive webtool "EEmonitor"** (Thrän, D. et al (2023)) with more than 1000 visitors and 110 data downloads since the release in Jan 2023.
(b) **Strategies to manage spatial trade-offs related to future deployment pathways for onshore wind power** (Lehmann, P., et al (2023); Tafarte, P., Lehmann, P. (2023); Meier, J.-N.,

Lehmann, P. (2022)). The main policy relevant insights have been summarized in a Policy Brief (Lehmann et al (2022)).

(c) **A CDR assessment framework** (Förster, J et al. (2022)), which can consider stakerholders preferences and has been applied for CDR concepts for Germany (Borchers, M. et al (2022)).

(d) **Assessment of stakeholder perceptions and the legal issues arising out of a large-scale ramp-up of CDR-technologies** (Markus/Schaller (2023)), considering pathways to subsurface, proposing among others the amendment of the carbon storage law (Markus, T. et al (2023)) and the implementation of a carbon storage monitoring (Otto et al. (2022)).

(e) **Open model "BENOPTex" to assess the competing demand for biomass in different energy sectors** (Jordan, M. et al (2022); Millinger, M. et al (2022)), and also integration of biobased CDR (ongoing). It was developed in cooperation with DBFZ and has been used to support the German RE strategy (Lauer, M., et al (2023)) and the German biomass strategy (ongoing).

Outreach / Impact

Our research focuses on the national scale but is embedded in the international scientific community (e.g., by coordinating a workshop and special issue on the spatial dimensions of RE use in the Journal of Environmental and Resource Economics, by coordinating a co-funded EU project in which the impact of fit-for-55 and REPowerEU packages on future intertwined pan-European energy systems is investigated, by contributions to EU research projects (on legal analysis of CDR), and by contributing to joint international reviews of CDR options).

The results support decision-makers via scientific councils (European Bioeconomy Stakeholder Panel, Deutscher Bioökonomierat, Klima- und Energiebeirat Sachsen, Thüringer Klimarat etc.), by providing dedicated model results for policy strategies, and by preparing policy briefs. In addition, we apply transdisciplinary research approaches which integrate the views of decision-makers throughout our research process. Activities range from joint workshops to joint publications (e.g., with the Federal Agency of Nature Conservation, Federal Environment Agency).

Next steps / Outlook

To support the shaping of energy landscapes sustainably, we aim to bring the developed methods and approaches on a harmonized scale and also join the approaches. The next steps are to (1) automate the mapping of RE and CDR locations in the landscape, (2) roll out the developed simulation and allocation methods over all land-related RE and CDR options (bioenergy, onshore wind, photovoltaic, hydro-power, biobased CDR), (3) strengthen data-driven approaches in our models, i.e. by including more physical land description parameters, (4) provide scenarios on the role of RE and CDR in a land-saving bioeconomy, (5) monitor tectonic social shifts that impact the bioenergy landscape using state-of-the-art deep neural network systems and incorporating the insights in partial equilibrium energy system models, (6) transforming the results of mathematical models into stories for better alignment of stakeholders, (7) identify and assess legal conflicts resulting from increases in land demand, and (8) intensify our international co-operations.

In preparation for regionalization (state level), efficient communication of outcomes, and understanding of the dynamics of the many model parameters in **BENOPTex**, a new user interface is being developed, and the use of machine learning and artificial intelligence algorithms is explored (Esmaeili Aliabadi, D., Chan, K. (2022); Esmaeili Aliabadi, D. et al (2023)).

We also aim to proceed with our collaboration in HGF. We cooperate in the joint activity of the HGF-CDR-network as well as the Helmholtz-Sustainability-Challenge and CCA activities, contributing to the Helmholtz RE atlas and co-leading the SYMCOM project on CDR.

Literature

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