INTEGRATIVE ENERGY INFRASTRUCTURE PLANNING TOOLS FOR CROSS-SECTORAL RESILIENCE AND FLEXIBILISATION CONCEPTS. [FFG BIOFLEX PROJECT]

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Synopsis

The dynamics of photovoltaics, wind power, and bioenergy shape the volatility of our energy supply, influenced by the time of day, season, weather, and developments in agriculture and forestry. **BioFlex** explores the fundamental commonalities in dealing with these fluctuations and the uncertainties in extrem events caused by climate change. The project targets modellers interested in a comprehensive and coherent analysis of the future resilience and flexibility needs in the energy system.

Introduction

Research on flexibilities in power systems is becoming increasingly important, but so far exceptional events due to (a lack of physical) resilience of infrastructures have been neglected in power market and power system models. In contrast, resilience research is predominantly concerned with disaster prevention, security considerations, and coping with sudden resource shortages. In the **FFG BioFlex project**, we combine resilience and flexibility concepts to provide a common basis for energy infrastructure planning.

Research goals

Sub-objective #1: Define a set of requirements for modelling resilience and flexibilisation concepts.

Sub-objective #2: Test proprietary tools to identify their capabilities and limitations.

Sub-objective #3: Formulate a guide for advancements in research, development, and innovation.

Methodology

In the FFG BioFlex project, we define **flexibility as the ability to move resources through time, space, and between sectors**. This option allows for balancing deficits with surpluses. The currently prevailing discussion of flexibilisation focuses on regular, well-known fluctuations, and thus on a limited risk space. We extend this space by including extreme events, considering resilience measures such as storage or redundancy as a special form of flexibilisation. Potential dangers of flexibilisation, such as the amplification of imbalances, are also considered. Examples of compound events which can stress power systems are e.g. cold related failure of power grid infrastructure during cold “dunkelflauten”, combined with increased charging of electric car fleets due to e.g. mobility demand induced during peak travelling times or storm related grid infrastructure failure with a concurrent drop in wind power production as turbines shut down in extreme winds, can be given here.

To incorporate the expanded risk and uncertainty space into energy infrastructure planning, we are developing a detailed requirements profile for planning tools. To identify the capabilities and limitations of our own tools, we conduct tests. Here, we use the MEDEA electricity market model (Boku) and the BeWhere bioenergy supply chain model (IIASA). This choice of models allows us to investigate **flexibility options on the interface between electricity and bioenergy supply**. Considering multi-

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sector coupling, also called infrastructure coupling or system integration, allows us to better understand resource shifting between sectors as a flexibility option.

The insights gained and results of the tests are used to create a research, development, and innovation (R&D&I) guide. The guide includes a SWOT analysis (Strengths-Weaknesses, Opportunities, and Threats), resource requirements, and an assessment of the likelihood of success for **strategic, integrative planning and implementation of cross-sector resilience and flexibilisation approaches**. Targeted communication in national and international networks as well as bilateral exchange with modeling experts in sister projects ensure the broader applicability of the project recommendations. In particular, the activities in the International Energy Agency (IEA) Bioenergy Technology Collaboration Program (TCP) Task44 on flexibilisation and system integration should be mentioned. The BioFlex project builds on the results of the first triennium of this Task [1].

Expected results

The FFG BioFlex project enables early identification and planning of synergies, trade-offs and coherence between sectoral infrastructure decisions. The opportunities arise from integrating assessment capacities for resilience measures and flexibility measures as well as in dealing with practically irreducible uncertainties. This helps to better represent climate change impacts on the energy system, regular variations in solar irradiance, wind occurrence and water supply, wind breakage, snow load, flooding, pest infestation and crop damage, as well as societal and trade transport risks in energy system models.

At the 18th Symposium on EnergyInnovation, we will showcase the outcomes of sub-objective #1, unveiling a model requirement catalogue shaped by an expanded risk and uncertainty space. This catalogue delves into various manifestations of uncertainties, encompassing variabilities and fluctuations, uncertain trends, extreme events, and intricate cascading effects between systems. Employing a supply chain network perspective, we pinpoint sources of uncertainty across nature, infrastructure, technologies, and society. **Table 1** provides a curated example for each category.

Table 1: Selected examples of uncertainties categorized by cause and expression

Cause / Expression	Nature	Infrastructure (links or edges)	Technologies (nodes or vertices)	Society (incl. market)
Variabilities Fluctuations	Seasons	Lead-times	Stock losses	Prices
Uncertain trends	Precipitation	Mode shares	Efficiencies	Demographics
Uncertain extreme events	Forest fires	Lock-downs	Disasters	Strikes
Uncertain cascadic effects	Cryosphere/ Hydrosphere	Power / Railservice	Internet / digi. manufacturing	Markets / innovative capacity

The Uncertainty Framework Table (UFT) concept, as introduced by Kirchner et al. [2], serves as the foundation for our study, extended to explore pathways of uncertainty propagation within current energy system models. This endeavour places emphasis on discerning various types of uncertainties, encompassing both reducible and practically irreducible uncertainties. It encompasses anticipatory methods, such as sensitivity and scenario analysis, as well as probabilistic, qualitative, and argumentative approaches, or even the option of acknowledging deliberate ignorance.

An innovative aspect of the BioFlex project is its approach to confront the dual nature of uncertainties, acknowledging both potential adverse and potential advantageous outcomes. Although this duality was identified by Knight [3] a century ago, contemporary uncertainty frameworks, like the one employed by the Intergovernmental Panel on Climate Change (IPCC) [4], predominantly encompass negative outcomes to streamline communication regarding the adverse impacts of the climate crisis. The findings to be unveiled at EnInno2024 will delve into the numerical considerations of balancing detrimental and beneficial outcomes of uncertainties within existing energy system models.

Referenzen

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