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# Of sailors and divers: How researchers use energy scenarios

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ABSTRACT

Scenarios are a key instrument to guide decision-making in the face of an uncertain future. In the field of energy, scenarios are often published to inform external stakeholders who are not part of the scenario development. This study explores how researchers, a key stakeholder group in shaping the energy future, use energy scenarios. It analyses the case of Switzerland, where several competing scenarios have been developed in reaction to the governmental decision to phase-out nuclear power. 16 structured in-depth interviews with researchers from different disciplinary backgrounds were conducted. While most interviewees use public energy scenarios, there are two contrasting user types. The first group, labelled *divers,* primarily uses scenarios as a data source, whereas the other group, the *sailors,* refers to them as plausible energy futures. We identified different interpretations of scenario content between *sailors* and *divers*, which result from the quantitative modelling on which contemporary energy scenarios are based. Due to a lack of guidance from modellers and missing qualitative information, energy scenarios are prone to misconceptions and distortions in their interpretation by external users.

## 1. Introduction

The contemporary energy system is extremely complex. The large number of relevant stakeholders, long investment horizons and structural interdependencies bring about a variety of dynamics that cannot be controlled and are difficult to predict [1]. As a consequence, policy-makers and business leaders have to make decisions under deep uncertainty [2]. At the same time, the central role of energy in modern economies [3] and climate change mitigation [4], create a considerable economic and political need to characterize and cope with such uncertainties. On account of this, various influential energy system players have been using scenario-planning – a foresight method intended to support long-term decision making under volatile conditions – since the second half of the 20th century (for a review, see [5]).

The benefits and effectiveness of scenario use in the field of energy has mostly been studied in two different empirical contexts. The first is the in-house development and use of scenarios by large organisations for the purpose of risk management or strategic planning (e.g. [6–10]). Much of that research is based on case studies, *Shell* being the most prominent example: The oil and gas company is famous for using scenarios to support their decision making processes since the 1970s [11]. The second empirical context is scenario use by public administrations. This is exemplified by the so-called *La Prospective,* a school of scenario building that has influenced the French government's five year planning since the 1960s [12]. Nowadays, a common characteristic is that public administrations commission highly specialised experts (hereafter referred to as "modellers") to develop scenarios [13]. Such modelling communities are often linked to public research institutes or private consultancies and have been established in many countries during the last decades [14].

In both of these scenario use contexts, the scenarios are designed for a specific target audience and purpose. Accordingly, there is typically a close collaboration between modellers who develop the scenarios and users who apply the scenarios. Users are actively guided by modellers and have access to counsel or additional information not provided in scenario reports [15]. Moreover, many users are directly involved in the scenario development process, which helps them to identify, understand and interpret the relevant information [16]. This user-modeller interaction is particularly important in the case of contemporary energy scenarios as they are based on computerized models to handle the complexities of the energy system [17]. Accordingly, many empirical studies that evaluate scenario use focus on its partly participatory development process (see [18,19]). As the scenario development provides an arena for discussion and promotes learning between different stakeholders, it is often regarded as even more relevant in supporting decision-making than a published report describing the scenarios [5]. Proximity to the scenario development process was accordingly identified as a key factor in conveying scenario-based insights effectively [20].

Nevertheless, institutions that develop or commission energy

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scenarios often make them available to the public. Examples include national authorities (e.g., [21], academic institutions (e.g., [22]), fossil fuel companies (e.g., [23]), environmental NGOs (e.g., [24]), as well as international institutions such as the International Energy Agency [25], the World Energy Council [26], or the EU [27]. Most scenario studies are therefore not limited to the small circle of addressees for which they are initially developed, but are made available to a wider audience. Publishing institutions, which sometimes have conflicting interests, generally claim to develop scenarios with an open outcome. Yet, they often inject their scenarios into the public discourse to convince relevant stakeholders (such as voters, shareholders or potential investors) of a specific vision of the future [28]. In that sense, the dissemination of scenarios is a way to articulate shared expectations in order to facilitate alignment around common goals, legitimise decisions, or gather support for forthcoming actions [29].

External users, such as researchers, journalists, non-governmental organizations, or voters, who have no interaction with modellers and do not participate in scenario development, may thus use scenarios as a basis for various decisions, to advance their own agenda, or simply to inform themselves [30]. In contrast to energy scenario users who are part of the development process, external users have sometimes been assumed to exist (see for example [31]), but not yet been studied empirically. To make a first step in this direction, this paper focuses on energy researchers – one potential group of external scenario users. Although devoid of direct decision-making power concerning the development of the energy system, energy research communities are catalysts for the dissemination of insights that are based on energy scenarios. Information provided by energy scenarios can directly impact research processes and results [32], which may in turn also inform decision-makers in administration and the industrial sector with the power to shape future energy systems [33].

As energy scenario use is inherently context dependent [34], we analyse one specific country and user group. We chose to focus on energy research in Switzerland, where a number of major national energy research programmes have been initiated since 2011 [35]. This led to a thriving energy research community that comprises of researchers with different educational backgrounds and thematic research foci. Several of the involved research institutions, but also industry actors and NGOs, develop and publish energy scenarios. Moreover, the country is in the process of adopting a national energy strategy that is in large parts based on a scenario study [36]. As a result, the diverse energy research community can choose from a variety of publicly available energy scenarios. This makes it an interesting case to study how energy researchers understand and use energy scenarios. More specifically, this study aims to explore what role energy scenarios play in energy research, for what purposes they are used and whether there are typical use patterns. These will be first steps towards insights into the finer mechanics of how energy scenarios generate and communicate knowledge when they are used by external users who neither interact with scenario developers, nor have participated in scenario development processes.

## 2. Background

### 2.1. Energy scenarios

Scenarios are plausible descriptions of how the future might develop based on a coherent set of assumptions [37]. The scenario concept comprises of a variety of methodological approaches and techniques, but typically, there are no probabilities assigned to scenarios, which distinguishes them from forecasts or predictions. Scenarios should therefore be treated as what-if projections that can be predictive, explorative or normative [38]. Because scenarios are applied in a variety of disciplines, scenario development techniques vary greatly, and there are a large number of different methodological approaches summarized under the label 'scenario planning' or 'scenarios analysis' [39]. One aspect that differentiates energy scenarios from scenarios in other fields is their reliance on computerized models [17]. Model-based energy scenarios are widely used in many countries [14]. TIMES and MARKAL for example, which are among the most popular energy models (see [40] for a description), have been used by more than 150 institutions in 63 countries [41]. To generate energy scenarios, energy models abstract from the complex reality by integrating model inputs into the model framework. For this process model inputs describing the existing energy system and assumptions about plausible future developments are needed. While model inputs can be derived from a range of sources, such as statistical offices, assumptions are made by consulted experts or by the modellers themselves. The resulting model output, usually in the form of key figures and a report, is what is commonly referred to as a *scenario*.

Energy models can vary in their purpose (e.g., forecasting, backcasting, simulation, or optimization), geographical scope (local, national, or global) or modelling paradigm (top-down, bottom-up, or hybrids) [42,43]. Distinctive models thus have diverging properties and apply varying levels of detail to different aspects of the energy system [44]. Most energy scenarios employ $CO_2$ emission reduction targets as exogenous normative constraints under which the model operates [45]. In investigating several countries, Chiodi et al. [46] showed that model choice is directly linked to both a country's position in climate policy negotiations and its resulting policy decisions. What is more, if enough decision-makers adhere to a certain energy scenario and act accordingly, it can develop a considerable transformative power [47]. An example which regularly spurs controversial discussions in energy science and energy policy communities is the discrepancy between the antithetic paradigms of top-down (e.g., system dynamics, general equilibrium, and econometric) and bottom-up (e.g., multi-agent, optimisation, simulation, or partial equilibrium) models [37]. Top-down models try to depict the economy as a whole and assess aggregated effects of energy policies, often in terms of monetary costs. The advantage of top-down models is that they allow users to account for feedback effects concerning economic growth, employment, or welfare. These models are highly influenced by neoclassical economic theory [48]. Due to their focus on macroeconomic developments, top-down models are ineffective in assessing technological progress [49]. Bottom-up models, in contrast, focus on technological development, innovation, a cost-efficient use of investment costs from a societal perspective (including externalities), as well as inter-sectoral changes and synergies. As a consequence, bottom-up models typically indicate lower costs for climate change mitigation than top-down models [50]. Following this logic, Karjalainen [51] found it problematic that most public administrations and most economists have tended to rely on top-down models when assessing the costs and benefits of acting on climate change.

### 2.2. Empirical context: Swiss energy scenarios and energy research

In the aftermath of the Fukushima accident of 2011, Switzerland decided to phase-out domestic nuclear power production, a decision that was subsequently approved in a public referendum in May 2017. For that purpose, the Swiss Federal Office of Energy (SFOE) had commissioned a consulting company to produce a scenario study of the Swiss energy future [36]. The resulting 900-page model-based scenario study *Energy Perspectives* provides a normative feasibility study of the nuclear phase-out based on three different scenarios [52]. One of these scenarios served as the basis for the Swiss Energy Strategy 2050 (ES2050). This strategy aims both at a massive expansion of renewable electricity production and a reduction in energy demand in order to achieve the envisioned energy transition at minimum cost [36]. *Energy Perspectives* is, however, not the only long-term scenario study of the Swiss energy system. Numerous energy scenarios focusing on the Swiss energy system have been developed and published by different academic and non-academic institutions since the decision was taken to