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Interpreting long-term energy scenarios and the role of bioenergy in Germany

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ABSTRACT

Defining the long-term development of Germany's energy sector, has been the subject of a series of studies carried out by governmental, industrial and independent interest groups. These studies play a significant role in energy political debate for understanding the long-term role of bioenergy in the national energy system. However, a deep insight and critical assessment of these studies is necessary to increase their transparency and traceability for policy and research. This article aims to provide with information for better understanding energy scenarios and to interpret the expectations of the role that bioenergy can play in 2050.

Firstly, 18 long-term energy scenarios were selected based on defined criteria, and analyzed in details in terms of their goals, methods, data used and obtained results. Furthermore, four specific bioenergy-related indicators were selected to carry out a quantitative analysis and interpretation across the selected studies. The results for the four indicators show a high uncertainty and a wide range of potential bioenergy development futures in Germany by 2050 – e.g. the sustainable domestic biomass potential ranges from 350 to 1700 PJ, the share of biomass in final energy consumption lies between 5 and 28% – principally due to the different key questions and methods and heterogeneous driving forces.

The study provides with recommendations for energy scenario users for quality measures (e.g. traceability and transparency of methods and data) and contextualization of the results

1. Introduction

Germany is aiming to develop and implement an efficient and environmentally sound energy system that is characterized by competitive energy prices. At the same time it strives to maintain high living standards and economic prosperity [1–8]. The proportion of renewables in Germany's energy balance is rapidly growing: renewable power generation grew from 16.4% in 2010 to 26.2% in 2014 [9], resulting in 157 Mt of avoided CO_2 emissions in 2014 [10].

In the aftermath of the Fukushima accident in 2011, the German government changed its stance on nuclear energy and approved an amendment to the nuclear power law [7,8] and the German parliament enacted a nuclear power phase-out by 2022 [11]. In 2011, a set of laws was passed that supported the implementation of the Energy Concept and an envisioned transition of the German energy system (known as “Energiewende”) by providing the necessary instruments and measures.

The German energy system is thereby undergoing a significant transformation in the short and medium term [12] with potential of achieving up to 100% renewable electricity by 2050 [13,14]. Although there is a political will to achieve the goals mentioned above, opinions are divided particularly with regard to the following aspects: firstly, in the way in which the energy system of the future should be constituted and secondly, in terms of the extent to which the various renewable energies will contribute to the energy mix. Finally, opinions are divided when it comes to identify the set of technologies that need to be promoted in order to achieve the forecasted goals.

In order to shed light on these questions and to explore a wide range of development options, a series of energy scenario studies have been independently commissioned by the German government, environmental groups and various energy sector stakeholders. In general, scenarios describe potential future developments of the system under investigation [15–17]. In particular, energy scenarios can be useful tools in (i) assessing energy sectors or system developments under certain assumptions, (ii) discussing various energy futures, (iii) integrating knowledge of different

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disciplines and stakeholders, and (iv) guiding and monitoring political decision making [18].

Energy scenarios can support the development of policy goals by evaluating a broad range of future options, as in the case of explorative scenarios. Another type of scenario, the target scenario, is implemented in political decision-making processes to analyze how a set of goals can be attained and their rate of achievement at a specific point in time. Any given scenario can therefore be characterized in terms of its main issues and goals, as well as in terms of the methods used and the degree of detail needed for the aspects under investigation.

Among renewables, bioenergy – i.e. energy derived from the conversion of biomass- has played a key role in Germany, making up to two-thirds of the supplied renewable energy. Biomass can be converted into all final forms of energy – power, heat and biofuel. This also implies that there is a broad range of possible biomass resources, conversion technologies and pathways. Bioenergy is characterized by a diverse and shifting policy related to it, as well as by a decision framework and stakeholders.

In recent years, cascading use of biomass has become an important asset of national biomass usage policies, aiming to a hierarchical valorization and use of biomass [19]. In this context, another important factor in these scenarios is the amount, quality and distribution of the available biomass potential. The promotion of this biomass use is reflected in the implementation of national bioeconomy strategies and roadmaps in Germany [20–22]. Such a shift in the role of bioenergy as a means of biomass valorization may have an important, and yet unknown, impact on its strategic, infrastructural and technological developments, and should be incorporated into long-term energy planning scenarios.

Thus it is difficult to deeply understand and directly interpret results derived from existing scenarios that determine the role and relevance of bioenergy. The executive committee of the International Energy Agency Renewable Energy Technology Deployment (IEA-RETD) has acknowledged the fact that a certain guidance framework is needed for scenario interpretation. It recently published a guide on energy scenarios for decision makers in order to improve their capacity to understand, evaluate and interpret models, including the drivers and values behind them, as well as the results of each scenario [23].

For this reason, our paper reviews a total of eight studies carried out in Germany, which describe, analyze, compare and explain the role of bioenergy within the national energy system. Our goal is to better understand and increase the transparency of energy scenarios and to interpret the expectations of the role that bioenergy will play in 2050.

2. Methodology

2.1. Scenario selection

A literature review was conducted to identify all energy scenario studies focusing on Germany's Energy Transition and the related Energy Concept targets (reduction in CO_2 emissions and increase in renewables). In addition, relevant international literature was reviewed to identify adequate global energy scenario studies which could be compared with the national scenario studies. These screened studies were published between 2007 and 2012. As part of a second screening process, studies were assessed based on their timeframe – up until the year 2050 (i.e. "long-term") –, their scientific credibility considering the applied analytical tools and assumptions, and the comparable information about the bioenergy sector. In order to account for different background motivations, we included studies made by public bodies, research institutions, non-governmental institutions and the energy sector itself. As a result, we selected a total of 18 normative and explorative energy scenarios from eight studies [13,14,24-29]:

- "Signals & Signposts Shell Energy Scenarios to 2050" – Shell 2011 [24] was selected in order to assess global energy system scenarios from an energy sector perspective. Shell has pioneered the development of plausibility-based scenarios, dealing with complexity and uncertainty over the past 40 years. It has developed scenarios as decision support tool for strategic enterprise development, considering long-term trends, based on plausible assumptions and quantifications. Most of the parameters in this study are available for Germany.
- "Energy Technology Perspectives – Scenarios and Strategies to 2050 – IEA 2008" [25], published by the International Energy Agency, was chosen as a second international reference, especially because it contains detailed and differentiated data on bioenergy technology and its usage, also including specific data for Germany.
- To represent the dedicated electricity sector, two scenarios included in the review study were: "Energy target 2050: 100% renewable electricity supply" – UBA 2010 [13] conducted by the German Federal Environment Agency (UBA) and "Pathways towards a 100% renewable electricity system" – SRU 2011 [14], a special report issued by the German Advisory Council on the Environment (SRU). These two studies enabled us to analyze scenarios prepared by national institutions with different motivational backgrounds.
- Four studies were included in the present research that represented the complete energy system. "Long-term scenarios and strategies for the deployment of renewable energies in Germany in view of European and global developments – Lead Study 2011" – prepared by DLR in 2012 [26] and "Scenarios for an Energy Policy Concept of the German Government" – by the Federal Ministry of Economics and Technology (BMWi) [27] were conducted by public and private research institutions on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the BMWi. Both studies aim to explore different ways of achieving the climate and energy goals set by the German government and outlined in the Energy Concept [3].
- In addition, alternative studies submitted by two of the most influential environmental groups, WWF and Greenpeace, were reviewed. Whereas government-related studies focus on scenarios for achieving already defined goals, WWF and Greenpeace aim to bring to the table a more ambitious blueprint for the transition of the energy system. "Blueprint Germany – A strategy for a climate safe 2050" – WWF 2009 [28] was commissioned by the WWF to examine Germany's energy policy concept with regard to further energy savings and GHG mitigation potential.
- Furthermore, because of the heated political and social discussions in Germany on carbon capture and storage (CCS), the study examines scenarios with and without CCS technology. Greenpeace released the most ambitious energy system study called "Climate protection: Plan B – A national energy concept to 2050" – Greenpeace 2009 [29]. Based on the Energy Policy Concept and other official studies, Greenpeace presents a scenario that allows for an early phase-out of nuclear energy and an additional phase-out of coal-fired plants.

Table 1 summarizes the analyzed scenarios, including their geographical scale, scope, scenario types (explorative or target) and model applied, as well as their main goal.