Energy Strategy Reviews 13-14 (2016) 236–247

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.ees.elsevier.com/esr

Energy security in a decarbonised transport sector: A scenario based analysis of Sweden's transport strategies

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ARTICLE INFO

Article history:
Received 22 December 2015
Received in revised form
25 May 2016
Accepted 14 June 2016
Available online 22 June 2016

Keywords:
Energy security
Mobility
Transition
Transport policy
Uncertainty

ABSTRACT

Previous research has shown that it is possible to decarbonise Sweden's road transport sector. This study develops a scenario based method and analyses the influence of external factors on energy security, focusing on passenger and freight transport. It does so by analysing the vulnerabilities and capabilities of five different climate mitigation strategies, investigating previous security scenarios and identifying uncertain drivers. These are used to develop four consistent exogenous scenarios using cross impact balance analysis. The vulnerabilities and capabilities of the five different strategies are then compared with the challenges faced in the scenarios and the robustness and adaptive capacity of the resulting systems is analysed.

The results shows that strategies which reduce the use of energy (increase efficiency or conservation) are robust, but that demand restrictions are perceived as undesirable by some interest groups. Biofuels perform poorly if too many other countries increase their use of biofuel, whereas electrification performs best when many other countries implement this technology. The strategies are not mutually exclusive and simultaneous implementation of some provides synergies for national energy security. Some directions for further research are suggested, such as framing energy security as subjective, i.e. a result of material and contextual factors that co-evolve.

1. Introduction

Swedish politicians from different parties have for several years shared the ambition to make the Swedish transport sector independent of fossil fuels by 2030 and Swedish society climate-neutral by 2050 (see e.g. Ref. [1]). Reducing emissions of greenhouse gases can be achieved through different means. Policies implemented so far have mainly resulted in i) fuel switching, i.e. imported oil has been substituted with imported biofuels and some car models that run on alternative fuels have been introduced; and ii) increased efficiency, enabled by replacing petrol cars with diesel cars.[1] An official government investigation [3] described additional measures deemed to be required to meet the goal of a fossil-independent transport sector, e.g. reduced demand, but the impact of these measures on energy security was not assessed. This is the focal point of the present study, in which the strategies proposed in that report are analysed in different futures. The structural changes that these strategies would impose mean that it is fruitful to expand the concept of energy security to security of energy services. In this study two energy services are analysed, surface transport of goods and passengers.

This study has two main research contributions. Firstly, a novel methodology is developed that can be used to assess energy security in uncertain futures. This is of interests to energy security researchers and analysts. The methodology draws from the field of scenario studies, relates capabilities and vulnerabilities of energy systems to the epistemologies of negative and positive security, and shows how a subjective definition of energy security can be useful to assess energy security in situations of dynamic and/or heterogeneous valuations of energy security. Secondly, the results of this study are of interests to policymakers that implement climate mitigation policies and want these to be coherent with energy security objectives. Sweden is the case analysed in this study but the results can also be of relevance to other countries that import fossil fuels and strive to reduce emissions of greenhouse gases.

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[1] Since 2011, the strong increase of diesel has contributed to higher nitrogen oxides (NO_X) emissions from passenger cars in Sweden [2]. NO_X cause local air pollution. Total NO_X emissions are declining, since increased emissions from diesel cars are compensated by reductions from heavy transport and petrol cars.

http://dx.doi.org/10.1016/j.esr.2016.06.004
2211-467X/

To secure energy supply, Sweden relies heavily on the existence of functioning international markets, on Swedish consumers having the financial means to purchase energy and on mechanisms for handling short-term disturbances provided by membership of the International Energy Agency (IEA) and the European Union (EU). Sweden does not have an external energy security policy of its own aimed at energy exporters and secure transit routes [4].[2] Being a small country, Sweden is unable to influence global energy markets and instead has to play by the rules set by other actors and adapt if the market environment changes.

The global landscape of energy, security and foreign relations has changed during the past decade and is likely to continue to do so. How it will change remains to be seen. Uncertainty is high, as are the stakes – a combination that has been referred to as "post-normal science" [7,8]. IEA [9] continues to assume economic growth similar to historic average and project higher energy use far into the future, as do some other experts, e.g. Maugeri [10].[3] Others argue that the assumptions underlying business-as-usual (BAU) projections are more or less implausible [12], at least in the long run [13]. Some propose that frequently used global energy assessment models generate overly optimistic scenarios for energy transitions [14], while others argue the opposite, that they are too conservative [15]. Moreover, the global stock of outstanding debt has increased to levels that create new risks for financial stability and security [16].

Some previous studies have used scenario planning to test the robustness of regional transport planning [17,18] and the adaptability of infrastructure policies to changes in demand [19]. However, the robustness and capacity to adapt to normative changes in energy and transport systems are seldom analysed, since scenarios are mainly used as a tool in these studies to envision desirable futures [18]. One exception can be found in Krumdieck, Page and Dantas [20], who studied how development of the urban form (e.g. spatial planning and population density) affected the capacity of a city to adapt to reduced availability of fossil fuels. A number of studies have also analysed how replacing fossil energy with renewable energy affects the vulnerability to higher fossil energy prices [21–23]. However, these studies have a narrow view of uncertainties, since they focus exclusively on economic threats and consequences. Watson, Gross, Ketsopoulou and Winskel [24] analysed the impact of uncertainties on the UK climate change targets and identified several uncertain factors, e.g. availability of bioenergy, that will affect achievability of these targets. The energy security implications of this were not assessed.

The aim of the present study is to explore implications for security of mobility and transport services if Sweden were to reduce the dependence of its transport sector on fossil fuels and to identify whether such a strategy is adaptive or robust to external factors. The main focus of this paper is to explore how structural changes of energy systems affect which exogenous physical threats the system is exposed to as well as system sensitivity to such threats and capacity to adapt (more details on what was analysed can be found in Section 2.2). Scenario analysis was used, as it offers a method to account for the uncertainty about how exogenous factors will evolve.[4] By posing the principal question of how different strategies would perform in different scenarios, the ambition is to identify hotspots, strategies that are sensitive to external factors and room for further research – not to provide an exhaustive impact analysis of all climate mitigation strategies. Material was gathered from previous studies, government reports and remittances expressing different stakeholders' valuation of the means to achieve a fossil-independent transport fleet.

The rest of this paper is organised as follows; Section 2 provides a theoretical background and describes the methodology. This Section is mainly of interest for researchers. Section 3 introduces Sweden's strategies to phase out fossil fuels. Section 4 assesses how these strategies could affect the vulnerability and adaptive capabilities of the transport system and Section 5 explores how the strategies perform in the different scenarios. These sections are mainly of interest to practitioners. Finally, Section 6 provides main conclusions and suggestion for further research.

2. Theoretical background and method adopted

2.1. Scenario generation

The success of a strategy is usually affected by factors that are external to the decision maker. Therefore, the decision maker needs methods to analyse: 1) What is uncertain and outside the influence of the decision maker; 2) how it affects the outcome of the strategy; and 3) how a strategy can be formulated that provides a desirable, or at least acceptable, outcome regardless of how the uncertain external factors develop. One such method is explorative scenario analysis – a method that can be traced back to American military planning in the 1950s (see e.g. Refs. [26,27]).

A scenario is a description of a plausible situation. Elements of ontology (i.e. the structural representation of the world) are not always spelled out explicitly in scenario studies, but should include at least two different aspects. The first is the families of entities that are included and the second is how they are connected and influence each other, i.e. a causal relationships that is either reinforcing, neutral or negative [28]. This study investigated previous explorative scenario studies to identify scenario drivers used as entities and how these are claimed to be connected. Many of the studies scrutinised were published outside academic peer-reviewed journals, for example reports from think-tanks and various research institutions. The studies should by no means be seen as a representative sample of all previous scenarios studies on energy security. However, they exhibit similarities as they contain a handful of drivers that are used later in the scenarios developed in the present study. Drivers and their causal relationships were identified using the PESTEL (Political, Economic, Social, Technological, Environmental and Legal) framework, see the appendix for an overview of drivers and relationships.[5] A sketch of the methodology used in this study can be found in Fig. 1.

The next step was to construct the scenarios. This study utilised the bottom-up approach, which departs from the ontology of complexity science. From this it follows that all drivers can be interdependent.[6] Cross impact balance analysis (CIB) was used to develop consistent scenarios with the assistance of the computer programme Scenario Wizard.[7] The first step of the CIB method is to

[2] Energy security covers both domestic politics and foreign policy [5]. Sweden has a history of being strong in the internal dimension but weak in the external [6].

[3] Many projections of oil extraction rates and prices during the past decade proved to be inaccurate; a validation of projections can be found in Hallock Jr., Wu, Hall and Jefferson [11].

[4] Some decision makers do not share the view that uncertainties should be considered. For example, the former Swedish minister of energy has said that "I think that one should see the reality as it is and make plans for the best outcome [rather than plan for alternative outcomes]. It is the best method to make sure that we make the most of our situation" [25] (author's translation from Swedish).

[5] A similar scenario development approach has been used previously (see e.g. Refs. [29,30]).

[6] The frequently used scenario axis technique is a top-down approach that assumes that two drivers are independent and the state of all other drivers can be deduced from a combination of these two [31].

[7] The program is freely available from http://www.cross-impact.de/.