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Biofuels for road transport: Analysing evolving supply chains in Sweden from an energy security perspective

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HIGHLIGHTS

- We analysed Sweden's supply and use of biogas, bioethanol and biodiesel.
- We analysed potential synergies between climate change mitigation and energy security.
- Biofuels can provide synergies.

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ABSTRACT

The use of biofuels for road transport in Sweden has increased during the past 10 years as policymakers stimulate demand in response to concerns about climate change. Using a supply chain approach, this paper analyses: (i) existing biofuel supply chains in Sweden (biogas, biodiesel and bioethanol) in terms of security of supply, and (ii) possibilities to achieve synergies between implementation of climate change mitigation practices and security of supply objectives, through increased production and use of biofuels.

We argue that synergies can arise when exposure to upstream market risk decreases, the risk of the feedstock does not correlate with the fuel that it replaces, producers can switch between feedstocks and end user vulnerability to disruptions decreases. In the current Swedish context, the features of the biogas supply chain make it the most beneficial option, followed by biodiesel. In the way it has been implemented, bioethanol is the least favourable option. The paper concludes by outlining how biofuels could contribute to security of supply in the future.

1. Introduction

Investigating the interactions between climate change mitigation and energy security is a growing field of research [1]. Renewable energy, biofuel in particular, is sometimes depicted in the policy sphere as a means to reduce greenhouse gas (GHG) emissions and simultaneously increase energy security, especially in the transport sector, which is dependent on oil products, see e.g. [2–4]. However, whether or not these two policy areas are synergetic depends on several factors, particularly the individual technological options implemented [5]. This implies that the level of coherence depends not only on the policy objectives, but also the instruments and implementation practices used [6].

Sweden is an example of a country in which policymakers have stimulated use of biofuels in the road transport sector in response to concerns about climate change. This has contributed to increasing the use of biofuels from less than 0.3 TW h in 2000 to 6.95 TW h in 2012 [7,8]. By 2012, the increase had also enabled Sweden to reach its EU-mandated target of at least 10% renewable fuels in the domestic transport sector by 2020 [3,9]. Swedish policymakers have the ambition to increase the use of renewables further and make the Swedish road transport sector "independent of fossil fuel" by 2030[1] [10]. However, apart from this providing the possibility to reduce import dependence [11], the interaction with energy security has not been thoroughly assessed.

There are varying perceptions of what energy security symbolises [12–14]. Johansson [15] proposed that interpretations of the

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[1] The meaning of "independent of fossil fuel" is not stated explicitly. We interpreted it as the Swedish Transport Administration, reducing the final use of fossil fuels in the transport sector by at least 80% from the current level [87].

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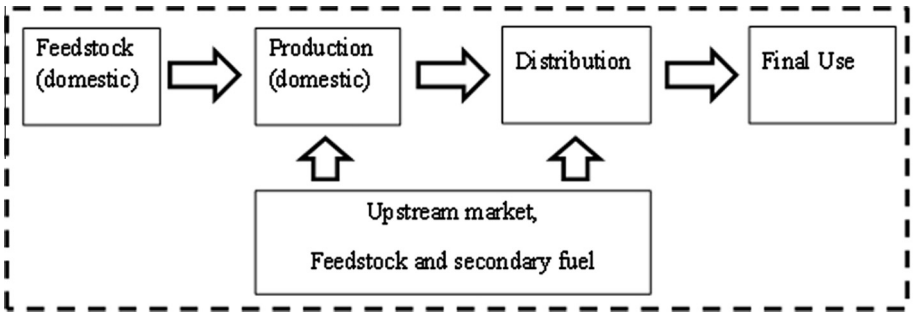

Fig. 1. Illustration of the five parts of the supply chain analysed and the system boundaries.

relationship between energy and security be classified as relating either to when an energy system is an object and the functionality of the system is to be secured, commonly known as security of supply or security of demand, or to when the energy system is an agent that causes and generates insecurity, for example as a result of a perceived political or economic value. In this study we examined the former, i.e. security of supply. Since coherence between climate mitigation and energy security policies was being analysed, we use the Swedish Energy Agency's definition of security of supply,[2] which is: a system that has capacity, flexibility and robustness to reliably meet users demand at an acceptable cost and the capacity of the market, government and users to respond to disruptions in the case of an emergency [16] (our translation from Swedish).[3] The study focuses on flexibility, robustness and capacity to respond. Sweden's security of supply strategy to date has mainly been to promote market liberalisation [17] and, for crude oil, international cooperation in the case of emergency, e.g. participation in the IEA emergency oil sharing mechanism and collaboration with other EU countries.

Energy systems can broadly be described as supply chains consisting of multiple interconnected stages, from resources to final energy use [18]. The aims of this study were to: (i) analyse security of supply for existing biofuel supply chains in the Swedish road transport sector and, (ii) analyse the potential of biofuels to increase security of supply in the future. When applicable, comparisons were made with the supply chain for oil products, the current dominant alternative for road transport in Sweden, as it offers a point of reference for emerging biofuel supply chains.

2. Method and approach

A strain can impact on any of the supply chain stages, but the consequences depend both on the strain (e.g. type and magnitude) and on the vulnerability of the system to the specific strain. For example, a system can be resilient or have the capacity to adapt to a changing environment while maintaining its functionality [19].

To enable separate studies of the various stages in the supply chain and comparisons of different supply chains, we divided the analysis to reflect the five stages of the supply chain: upstream market, domestic feedstock, domestic production, distribution and final use (see Fig. 1). Note that imports can be both feedstock and secondary fuel, but we analysed them in one cluster.

The factors we analysed for the respective stages in the supply chain are outlined below with reference to previous research.[4] Data were taken from government institution reports and statistical databases to obtain information on each part of the supply chain. For the analysis described in section four, we also used data from previously developed scenarios of how the Swedish road transport sector could become independent of fossil fuels. We analysed four different supply chains, at the national level, based on three final energy carriers; biogas bioethanol and biodiesel from fatty acid methyl esters (FAME) and hydrotreated vegetable oil (HVO).

2.1. Imports of feedstock and secondary fuel

Evaluations of the upstream energy market risk typically assess diversifiable and/or systematic risk using either dual-diversity indices [20] or financial portfolios [21,22]. Sweden does not have a foreign policy-related security of supply policy and the choice of import sources is therefore determined by market factors rather than bilateral trade agreements. Therefore, the main concern regarding oil in the Swedish context is systematic risk, as the upstream market is liquid, the commodity is fungible and short contract lengths are used [23]. Reducing the exposure to upstream market risk requires a reduction in imports. Several previous studies have assumed that import dependence is negative for security of supply, see e.g. [24–26]. However, contrary to common belief, the ability to import can be positive or even essential, for example if domestic production is damaged, as was the case during Hurricane Katrina, when the US increased its imports of crude oil [27]. In the present study, import dependence was therefore only used to measure exposure to upstream market risk and the optimal level of energy independence was not assessed. Furthermore, the risk associated with the imported feedstock and secondary fuel was compared with the risk associated with crude oil, since renewables have been proposed as strategy for hedging against uncertain and volatile prices of fossil fuel, see e.g. [28,29].

2.2. Domestic feedstock

Domestic feedstock was analysed as regards availability. Previous studies, based on fossil resources, have analysed the availability of resources using indicators such as the reserves to production ratios [26]. Energy supply chains that utilise renewable energy are dependent on flows instead of extracting stocks. For example, seasonal variations in crop yield and competition with other sectors, such as food production, may restrict the amount of available resources [30]. A previous study has indicated a low risk for agricultural output for Sweden, measured as yearly variability of agricultural production [31]. Therefore, we did not evaluate the variability. Instead, we evaluated the availability of feedstock as the domestic potential.

2.3. Domestic production

The domestic production infrastructure was evaluated in terms of its capacity (measured as installed domestic production

[2] Energy security can be approached from different epistemologies. Cherp and Jewell [88] argue that policy concerns should be the starting point when defining energy security. We assumed here that the Swedish Energy Agency's definition reflects Swedish policymakers' concerns.

[3] The adopted definition has similarities with general definitions such as "low vulnerability of vital energy systems" [89].

[4] For an overview of different valuation methods see [90].