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Forest-derived methane in the Swedish transport sector: A closing window?☆

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ABSTRACT

Forest-derived methane could complement biogas from anaerobic digestion as a transport fuel. The conditions for a systemic transition have been analyzed in this article. The analysis contains three blocks: the vehicle gas development, the policy framework, and commercial projects to produce methane from forest biomass. The results reveal that several conditions for a systemic transition are in place. There is established infrastructure for feedstock supply and biofuels distribution. Infrastructure development is an important albeit not determining factor. Private and public actors have advanced plans for commercial scale plants, technological know-how, and experience from a demonstration plant. However, a major barrier for a systemic transition is the low predictability of Swedish policy instruments. The Swedish government is not free to design policy instruments but must consider compatibility with the EU framework and has changed the energy tax on biofuels several times to avoid overcompensation according to the EU regulation. This has contributed to the low predictability. The interviewees have suggested several concrete policy instruments. However, they have also emphasized that the exact design of the policy instruments is less important than the predictability of the support.

1. Forest-derived methane and biogas from anaerobic digestion in the transport sector

1.1. Early enthusiasm for biofuels

The prospects for forest-derived transport fuels in Sweden have changed over the last decade. In 2006 the government announced a strategy to decrease the dependency on fossil fuels (Government of Sweden, 2006). The use of gasoline and diesel would decrease 40 – 50% by 2020. Forest-derived transport fuels were an important part of the strategy. The strategy included policy support to demonstration and full-scale plants as well as distribution infrastructure. Concrete economic policy instruments were suggested, including tax exemptions and transport fuel certificates. Forest-derived transport fuels were considered as a realistic option to reach the target by 2020 together with other renewables. Electrical vehicles were only mentioned briefly.

In 2008 the government presented the ambitious target of a vehicle fleet independent of fossil fuels by 2030 (Government of Sweden, 2008). This was seen as a first step towards the target of zero net GHG emissions from the energy supply by 2050. In 2013 a thorough government inquiry proposed policy instruments to reach these targets (Government of Sweden, 2013a). The inquiry recognized that both biofuels and electrical vehicles were needed to reach the target by 2030. Specific instruments were also suggested to support forest-derived transport fuels. The report received much attention in media and by the research community. However, three years later the proposed measures have not been implemented.

1.2. Forest-derived methane – state of the art

The Swedish forest holds a significant resource potential for transport fuels (Staffas et al., 2013). It is also the feedstock for large industry branches, e.g. pulp and paper, sawn wood products, and solid biofuels. The markets for these products are often global. Other potential products from forest biomass include textiles and bioplastics. The use of forest biomass in transport fuels production must thus compete internationally with both incumbent and upcoming industries.

There are different and sometimes competing production pathways for biomass to biofuels (Hellsmark and Jacobsson, 2012; Kirkels, 2014). Some pathways need dedicated distribution infrastructure and

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vehicles, while others are compatible with the current systems, i.e. drop-in fuels. Forest-derived methane[1] is compatible with the existing distribution infrastructure in large parts of the more densely populated parts of Sweden, since it is interchangeable with vehicle gas. Significant research and development efforts are being put into forest-derived methane and the energy company Göteborg Energi commissioned a demonstration plant in 2013. It may generate 160 GWh methane fuel per year. A new upscaled plant was originally planned that would generate 800 GWh of methane per year[2] (Börjesson et al., 2013; Gothenburg City, 2012; Hansson and Grahn, 2013). The implementation of the second phase is currently on hold; the company estimates that it would not be profitable given the current oil price and policy support. Other companies observe this development closely, e.g. the company E.ON that has advanced plans for a full-scale plant which could produce 1 600 GWh of methane per year (Börjesson et al., 2013; EON, 2015; Grahn and Hansson, 2014). The methane production from one such large-scale plant would be equivalent to the entire current use of vehicle gas in Sweden (SEA, 2015a). The vehicle gas demand must thus grow significantly to allow for such an investment.

1.3. Vehicle gas development and prospect

The use of vehicle gas amounted to 1 553 GWh during 2014 (SEA, 2016). It contains a mixture of upgraded biogas and natural gas, since the production of upgraded biogas is not sufficient to meet the vehicle gas demand. The distribution companies have voluntarily agreed to maintain a minimum share of 50% biogas (Strauch and Krassowski, 2012). The volume share was 63%[3] during 2014 and it increased to 74% during 2015. The share increased because the production of upgraded biogas continued to grow while the vehicle gas sales remained constant (Statistics Sweden, 2016).

The resources suitable for biogas production through anaerobic digestion are limited. The practical resource potential from residues and energy crops in Sweden has been estimated to 8.9 TWh per year (Lönnqvist et al., 2013). However, the cheapest and most accessible resources, i.e. sewage sludge and food waste, are to a large extent already utilized. Forest-derived methane may thus be needed if the vehicle gas demand increases again.

1.4. Aim and research questions

The establishment of a new socio-technical system such as the chain for production and use of forest-derived methane may be understood as a systemic transition. A systemic transition comes about through interactions between the *niche*, *regime*, and *landscape* levels (Geels and Schot, 2007). In order for methane from forest-derived biomass to be competitive, it must be so towards biogas from anaerobic digestion and also compared to other pathways from forest biomass to transport fuels. The technology has developed at the *niche* level although the competitiveness may improve further through learning-by-doing (Hellsmark and Jacobsson, 2012; Kirkels, 2014; Åhman, 2010). Forest derived-methane has not yet reached a commercial breakthrough and it has not established as a sociotechnical *regime*. However the regime level presents relatively favorable conditions for a systemic transition: presence of commercial actors, infrastructure for feedstock supply and biofuels distribution, as well as policy support. Policy instruments have supported the development in Sweden during a long period, through research and development, investments support, and different measures to stimulate the demand side.

There is a gap in the understanding of barriers for a commercial breakthrough for this technology and the importance of consistent policy support that addresses the barriers. *This research aims* at increased understanding of the conditions for a systemic transition and the *specific research questions* are:

- Why has a systemic transition not yet come about given that several conditions at the regime level are in place?
- How could policy support better address techno-economic and institutional barriers for a systemic transition?

2. Models and methods

2.1. Models

This article uses the theoretical framework of Geels (2011, 2004, 2002) as well as Schot and Geels (2008) for the understanding of how a new socio-technical system – forest-derived methane in transport – may come about through a systemic transition.

Geels uses the approach of *system-actor-institution*. The socio-technical *system* of interest for this article is mainly production, distribution, and use of fuels in the transport sector. *Actors* are the current and potential fuel producers, distributors, and end-users, as well as the incumbent forest industry. *Institutions*[4] such as the Swedish government and its subordinate body the Swedish Energy Agency may regulate the system and support a systemic transition through policy instruments.

Another approach by Geels is the *multilayer perspective*, which contains the levels *landscape, regime*, and *niche*. The socio-technical system analyzed in this article is located at the *regime* level. The regime level contains actors such as the fuel producers, users, and distributors. Governmental institutions as well as the regulations and policy instruments they have set up are also situated at this level.

The *landscape* level includes macro-economic and macro-political factors. Changes in the landscape level typically take place slowly over decades although the oil price drop in 2014 is an example of a landscape level change that happened quickly.

The *niche* level represents protected markets, universities, and other environments where technology may develop. The gasification technology is located at this level where research at universities has been supported by the Swedish government during a long period.

The socio-technical regime may change as a result of pressure from the landscape (top-down) and/or as a result of technologies emerging from the niche (bottom-up). Systemic transitions may thus take place at the regime level through interactions with both landscape and niche levels. If changes at all levels favor a transition, there is a *window of opportunity*.

A systemic transition may follow different transition patterns, e.g. substitution or stepwise reconfiguration (Geels and Schot, 2007). A substitution consists of one system replacing another at the socio-technical regime level. It may be initiated by a strong landscape pressure at a moment when niche innovations have developed sufficiently. Stepwise reconfiguration does initially not replace an existing system and may occur without a strong landscape pressure. Innovations may be adopted as add-ons or as component replacements. However, new combinations of new and old components gradually reconfigure the system (Berkers and Geels, 2011).

2.2. Methods

This article is divided in three blocks: i) the vehicle gas development, ii) the policy framework, and iii) commercial projects to produce

[1] This fuel is called forest-derived methane throughout the article, but the terms synthetic natural gas (SNG), bio natural gas (BNG), and bio synthetic natural gas (bio SNG) are also common.

[2] In addition, the plant has capacity to deliver heat (15 – 19MW) to the district-heating grid and to generate electricity (4MW).

[3] Measured by energy content, the share is slightly lower since biogas has a lower energy content.

[4] Geels treats rules and institutions as one concept that co-ordinates and structures activities.