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On the road to fossil-free public transport: The case of Swedish bus fleets

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HIGHLIGHTS

- The penetration of renewables in Swedish public bus fleets reached ca. 60% in 2014.
- Public bus emissions per vehicle-km have decreased by 43% between 2007 and 2014.
- Efforts are needed to improve energy efficiency in bus transport.
- Electricity is likely to receive increased attention according to expert survey.

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ABSTRACT

Public transport is important for Sweden to acquire a fossil-fuel independent vehicle fleet by 2030. The aim of this paper is to assess the status of Swedish public bus fleets towards decarbonization, and explore factors affecting regional performance variations and fuel choices. Environmental performance indicators such as renewable fuel shares, CO_2 emissions, and energy efficiency are analyzed nationally and regionally. Fuel preferences and best practices are investigated through a survey and interviews with experts working with strategic planning at Public Transport Authorities. Almost 60% of the bus transport volume ran on renewables in 2014 compared to 8% in 2007, but regional variations are significant, partly due to factors such as driving conditions, bus and fuel types, typical trip lengths, and climatic conditions. However, there is no strong correlation between population densities or bus transport volume and the share of renewables achieved. This places political will, strategic planning and policies to promote public transport as key factors affecting renewable fuel deployment. Environmental factors are a priority when choosing fuels, while barriers to renewable fuels are mainly economic and political. Meanwhile, despite the overall progress, achievements in energy efficiency improvement are falling short in comparison to emissions reduction and adoption of renewable fuels, thus requiring further attention.

1. Introduction

Sweden has set the ambitious goal of acquiring a fossil-fuel independent vehicle fleet in 2030. This goal implies reducing significantly the share of fossil fuels in the transport sector so that the vehicle fleet will not be highly dependent on fossil fuels for its operation in the future as is the case today (Regeringskansliet, 2013). This is a key step towards the country's target to achieve CO_2-emissions neutrality by 2050 (Regeringskansliet, 2013). The public transport (PT hereafter) sector plays an important role in this context, as it represented 27% of the total amount of passenger-kilometers in road transport in 2014. PT responds for only 2.7% of domestic road transport emissions in Sweden (Naturvårdsverket, 2015; Svensk Kollektivtrafik, 2015a; Trafikanalys, 2015a). An ambitious target has been set to run 90% of the total vehicle-kilometers of PT on renewable fuels by 2020 while at the same time increasing the share of PT (SKL, 2014a). Renewable fuels are defined as fuels produced from renewable sources, such as biofuels, hydrogen fuel or electricity originating from renewable energy sources.

In line with the energy and climate policies of the Swedish government, and the objectives set by the Swedish Public Transport Association (Svensk Kollektivtrafik – SK hereafter), major efforts are being made to make public bus transport a renewables-based, climate neutral and attractive option throughout the country. So far, this transition to renewables has been driven to a great extent by effective strategic planning from regional public transport authorities (PTAs hereafter) as well as fuel taxation that make renewable fuels a competitive choice. As a result of the efforts made in the last few years, renewables accounted for almost

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60% of the fuels used in the whole public bus fleet in 2014 compared to approximately 8% in 2007. This is a much higher share than the 23% renewables for all Swedish buses in traffic (Trafikanalys, 2015b) and the 12% of renewables in Swedish road transport overall (Swedish Energy Agency, 2015). However, strong regional variations can be observed when it comes to the share of renewables in public buses.

In this context, it is worth evaluating what has been achieved so far and how it was achieved, and addressing the challenges that lie ahead so that successful policies can be designed to reach the 90% goal. The aim of this paper is to make a regional assessment regarding the target towards fossil-free bus fleets in PT, and explore which factors influence performance variations and fuel choices. We highlight challenges and fill information gaps through a closer examination of the performance of regional bus fleets. We are interested in how the penetration of renewables in buses has varied in different regions in Sweden. *What types of fuels are preferred and why? What challenges are still to be addressed and what are the lessons learnt?* By following the narrative of the transition of public bus fleets to renewable fuels, we identify the actors involved, the sustainability choices they face, and what is missing from the current policy landscape to promote the transition further. We identify patterns established in past years as well as best practices worth disseminating.

1.1. Literature review and analytical approach

There is a gap in energy policy research related to public transport in Sweden. The role of biofuels in Swedish road transport has been analyzed from a policy perspective in various studies, e.g. Börjesson et al. (2014), Sanches-Pereira and Gómez (2014), Holmgren (2012) and Stelling (2014). However, these studies do not focus on the particular role of PT in transport. An analysis of the role of PT in a fossil-fuel independent vehicle fleet is explored by Nilsson et al. (2013), where the need for more systematic policy analyses in Swedish PT is pointed out.

Although the Official Report SOU 2013:84 *Fossil-freedom on the way* (Regeringskansliet, 2013) highlighted the importance of PT for realizing the goal of fossil fuel independence, it failed to propose concrete measures to foster further technology and fuel transition in the sector. In fact, various stakeholders have criticized the lack of incentives for the PT sector in their inputs to the official consultation process. SK suggests that more instruments for urban development in combination with PT planning should be defined to favor a transition towards renewables (Goldmann and Persson, 2014).

Looking at existing international literature, Xu et al. (2015) discuss the factors influencing decisions on bus technologies and fuels, and conclude that the optimal combination of technology and fuel for minimizing emissions depends on the location in relation to complex factors such as weather, terrain and duty cycle. Energy efficiency in buses is discussed by de Abreu e Silva et al. (2015), where factors affecting the energy efficiency in buses operating in Lisbon are explored using regression models. The authors conclude that the main factors affecting energy efficiency are vehicle types, speed and driving conditions (terrain and routes). The impact of different fuels on energy efficiency is not discussed because all buses examined were operating on diesel.

Ou et al. (2010) suggest that integrated policies are needed to promote various electric bus technologies as a future PT option and indicate that further research is needed for improving vehicle fuel efficiency. The focus is on the emissions, while the role of various stakeholders in promoting alternative fuels is not discussed in detail. Wang et al. (2015) simulate emissions, energy efficiency and fuel consumption for bus fleets in the three most developed Chinese regions. Their study points out the importance of diversifying the fuel mix at regional level for achieving simultaneous energy savings and emissions reduction.

In Turcksin et al. (2011), Multi-Actor Multi-Criteria Analysis (MAMCA) is applied for assessing biofuel options for Belgian transport in relation to the binding targets of the Renewable Energy Directive (RED) for 10% renewables in transport. The authors identify the options preferred by stakeholder groups, indicating that government actors seem to strongly prefer renewable alternatives. The study contributed to better understanding of stakeholders' positions regarding fuel choices, which in turn can serve to better design policy instruments aimed at decarbonizing the transport sector.

Hung (2006) investigated the impact of policy instruments such as fossil fuel taxation and subsidies on non-fossil fuel deployment on private transport. The author concluded that costs are the *"single most important factor"* for switching fuels. However, we argue that for PT other factors such as social and environmental goals may come into play and affect fuel and policy instrument choices. Indeed, Faivre d'Arcier (2014) argues that the increased ambition towards sustainable mobility is increasing operation costs and putting pressure on urban PT. At the same time, the author highlighted the lack of reliable and/or comprehensive PT statistics.

There are no studies mapping emissions and efficiency indicators for regional public bus fleets, and connecting those to fuel choices and policy implications, which also motivates this study. The use of secondary data from a national database gives the opportunity to extend the scope of empirical data from local bus lines or theoretical data from meta-analyses to real data for larger regional fleets. We have identified relatively few studies using real driving conditions for bus emissions and energy efficiency. FRIDA, the Swedish database for bus fleets, is unique and provides a rich data source for analysis not found elsewhere.

We also explore the role of stakeholders involved in policy implementation for achieving environmental goals set for PT, improving bus technologies and choosing alternative fuels. In this study, input from a PT stakeholder survey adds value to the discussion on challenges and information gaps in policy-making among decision-makers and technical experts. Drivers and barriers to renewable fuel adoption connected to fuel choices are discussed in the survey. In this way, we explore whether factors other than the purely technological ones identified in previous studies affect fuel consumption and technology choices.

The Swedish case is remarkable in an international context because of the highly ambitious goals for alternative fuels in PT, and the fast deployment achieved for these fuels in buses. Through a regional comparison we are able to highlight differences and extract valuable lessons and best practices, which offer insights that are useful both domestically and internationally.

In this paper, the focus is exclusively on bus as a means of PT (the term "public transport" is used here interchangeably with the term "public transport by bus"). This separation is important since addressing all PT modes together would not provide insight into the particular features of bus transport. The majority of vehicle-kilometers of the other means of PT (i.e. train and tram) are driven on electricity, which is mostly supplied from renewables or carbon-free sources in Sweden. In 2013, 87.1% of the transport volume on train and 100% of trams run on electricity (Svensk Kollektivtrafik, 2015a). PT via bus accounts for 90% of the total volume of bus transport in Sweden (Trafikanalys, 2015c). Hence, studying the buses operating in Swedish PT has high relevance to bus transport overall. The data presented refer only to buses operating in PT.

Following this section, public bus transport in Sweden is presented in more detail in Section 2, and the analysis methods are described in Section 3. In Section 4, we map the bus fleets' performance when it comes to environmental indicators, such as

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