Beyond Diesel:
An actor-oriented approach to electrification

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1. Introduction

In 1972, Nathan Rosenberg argued that the adoption of new technologies was, "without doubt", one of the central questions of economic growth (1972, p. 3). Now, more than half a decade later, we can make a similar statement. Namely that the rate at which *carbon-free technologies* are adopted and incorporated into the productive process is, without doubt, one of the central questions of *climate change mitigation*.

Today's companies face significant pressures to shift from unsustainable modes of production to more sustainable ones. For businesses that currently rely on fossil fuels to create and deliver value, this calls for adoption of carbon-free technologies, i.e., innovations that make use of (green) electricity or other alternative fuels instead of diesel or petrol. Not only that, to meet the global targets of climate change mitigation, this shift must be quick, at least when compared to the rates of adoption identified historically (cf. Enos, 1962). So, while past innovation scholars have regarded the *slowness of diffusion* to be an inherent trait of the process (e.g., Hall and Khan, 2003; Rosenberg, 1972), researchers, practitioners, and policymakers are now exploring ways to speed up this process, or as they proclaim: to find ways to "accelerate the sustainability transition".

To accelerate a process that otherwise can take decades clearly requires a joint effort from multiple actors, each with different roles in the process. This is especially true for technologies that are embedded in complex systems with a high degree of interconnectedness between social and technical aspects (Markard et al., 2012). Adoption is not only a question of purchasing a new technology or not, but is often dependent on regulations, complementary technologies, and infrastructure as well (Köhler et al., 2019).

1.1 Research Background

The transport system is often characterized by its complexity and interconnectedness. More than a century ago, Cooley wrote that "the character of transportation as a whole and in detail, at any particular time and throughout its history, is altogether determined by its inter-relations with physical and social forces and conditions" (1894, p. 40). At that time, the internal combustion engine was still a novel innovation and its impact on the climate would linger many decades to come. It was not until the 70's and 80's that energy issues started to engage transportation researchers (VTI, 1983). Yet even then, these research efforts were not motivated environmental concerns. A document published by the Swedish National Road and Transport Research Institute in 1983, reads:

> *Even within transport research, energy issues have been at the center, not least truck transports have become objects of great interest. Behind these studies, of course, is the rapid price development of petroleum products and the fact that society will face a continuing shortage of oil products.*

In retrospect, we know that the biggest energy issues in the transportation was neither the price development of petroleum nor the shortage of oil, but rather the pressing challenge to avoid fossil dependence, break carbon lock-ins, and enable a shift from internal combustion engines to carbon-free technologies. However, identifying the problem is one thing, solving it is another. Even though large investments are currently being made to enable a swift substitution from the internal combustion engine to electric drivetrains, and despite tightening regulations pertaining to greenhouse gas emissions and CO2 (Gnann et al., 2022), adoption to battery electric vehicles is still in its infancy. In particular, we see that diffusion is slow in the case of trucks and goods transportation (Xie and Rodríguez, 2021). In 2022, the number of electric trucks sold worldwide amounted to 1.2% of the total

truck sales (corresponding to 60 000 medium- and heavy-duty trucks) (IEA, 2023a). This can be compared to the sales of electric cars which reached 14% that same year (IEA, 2023b).

To understand the challenges of adopting carbon-free technologies in the transport sector, we can start by posing the question of *why is it so difficult*? Various answer to that question can be found depending on the perspective we take. The traditional economist may posit that it is because of the superior performance of fossil fuels compared to its alternative fuels (ref), while an institutional economist may argue that it is the result of rigid social and legal norms and rules (e.g.,…); the political scientist could point out that carbon-free technologies require new regulations and policy instruments (e.g.,…), while the psychologist may argue that adoption is hindered by individual's attitudes towards change and uncertainty (e.g.,..) ; and so on. The range of perspectives that can be used to study carbon-free technologies is not surprising. A widespread diffusion of carbon-free technologies in the transport sector would require changes across multiple dimensions, including in the technologies themselves, but also in markets, user practices, cultural meanings, infrastructures, policies, industry structures, and supply chains (Köhler et al., 2019). Furthermore, such changes to the transport system are influenced by a range of actors and social groups from academia, politics, industry, civil society, and households (ibid). With this, it becomes clear that the path towards carbon-free transports is far from straightforward. When adding the notion of *speed* to this equation, the challenges become even more apparent.

Given this complexity, it is well established that the generation, diffusion, and utilization of carbon-free technologies requires a network of agents interacting (e.g., Markard and Truffer, 2008). As we will see, however, the agents in such networks are seldom given equal attention, neither in research nor practice. More specifically, the focus tends to be on corporate, technology and policy actors, while the users of technology, representing the demand side, are largely neglected (Grin et al., 2011, p. 5). While this may be unproblematic when the element of *speed* is secondary to the diffusion process, I argue that the same cannot be said if we wish to "accelerate the sustainability transition". In other words, if we only concentrate on "certain supply side consideration", as Rosenberg did in his seminal paper from 1972, we may understand *why diffusion is slow*, but we will learn less about *how we can make diffusion quicker*.

1.2 Research Aim

The overall research aim of this thesis is to understand the role of *users* when faced with discontinuous technological change. More specifically, I intend to study trucking companies to understand how they are contributing to, and affected by, the diffusion of battery electric trucks. To achieve this aim, the following research questions are formulated:

(1) How are trucking companies affected by electric truck diffusion?
(2) How can trucking companies contribute to electric truck diffusion?

Inspired by Markard and Truffer (2008), I start by exploring the technological innovation system (TIS) of electric trucks before zooming in on the role of the trucking companies. The reason for this is twofold. First, this intends to inform the reader of the context in which trucking companies are operating, something that this framework has proven useful for before (e.g., Bach et al., 2020; Bauer et al., 2017). Furthermore, I recognize that a *role* does not stand on its own, but "always bears a […] relationship to one or more roles, change in one role always means change in a system of roles" (Wittmayer et al., 2017). Thus, even if the thesis has a primary focus on one type of actor group, I still acknowledge that transitions are "multi-actor processes, which entail interactions between social groups" (Geels and Schot, 2010, p. 11).

This is followed by an examination of the different roles that trucking companies enact in the system. As prior theory is lacking, this will be explored with open-ended inquiries of an exploratory nature (Edmondson and McManus, 2007). The research questions will be answered using qualitative case studies, with data collected in various ways, including interviews, observations, and document analysis (Eisenhardt, 1989). When searching for appropriate cases to study, it quickly became apparent that the industry is highly heterogeneous. Thus, to answer the research questions, I recognize a need to also explore the different trucking companies there is since, depending on the type of business in question, they will likely vary in the ways they are affected by, and are able to contribute to, the diffusion of electric truck diffusion. This includes questions of organizational structure, business models, strategies, and resource endowments, which becomes integral for the purpose of this thesis given their impact on the role of firms. Thus, before choosing appropriate cases to study in-depth, I intend to conceptualize the industry and develop business archetypes that can guide the case selection going forward.

With this thesis, I intend to make two primary contributions to literature which hopefully can serve the interest of both researchers and industry practitioners. First, in line with Farla et al. (2012), I believe that "if we understand the struggles of actors with competing interests and which kinds of resources they can mobilize in support of their goals, we will better be able to assess the conditions for sustainability transitions to materialize". By studying trucking companies and explore the barriers to, and drivers for, diffusion of this new technology, I hope to shed light on *struggles* and *conflicting interest* that otherwise risks being overlooked in the discourse of electrification. This would not only be interesting for those trying to understand sustainability transitions, but also for industry practitioners, in particular those that are authorized to mobilize resources to support *others*. For them, knowledge about the struggles of users, who ultimately are the ones deciding whether to adopt new technology or not, can guide the resources being distributed in the system. Second, I believe that the users, who in this case are represented by the trucking companies, often are underestimated sources of innovation in themselves. Neglecting the users thus risks overlooking their potential contributions to the system, e.g., in the form of users' contextualized, local knowledge (Grin et al., 2011), benefits of cocreation (Bergek et al., 2015), or feedback mechanisms from the demand side (Randelli and Rocchi, 2017).

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