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Herausgeber: J. Biethahn† • L. M. Kolbe • M. Schumann

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Understanding Drivers of Electrification of Transportation Systems in a Commercial Context

The Case of Vehicle-to-Grid Applications in Electrified Fleets

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vorgelegt von

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To achieve great things, two things are needed: a plan and not quite enough time.
- Leonard Bernstein

This quote from the fascinating Leonard Bernstein often comes to my mind, when reflecting on the most pressing matter that humankind is facing today: the mitigation of global climate change. I think, we can easily agree that we do “not [have] quite enough time”, however, “a plan” seems to be lacking. Contributing to this plan is what drove the research included in this thesis. The interconnected, IS-enabled transformations of the energy and transportation sector offer immense potential to achieve a more sustainable world.

Apparently, Leonard Bernstein was a doctoral researcher at some point in his life, too. How else could he have pinpointed the key to a successful dissertation project so precisely?

The past three years have been an exciting, challenging, and joyful time. Not only have I had the opportunity to become a researcher, but also a home-office-expert, triathlete, conference-attendee, feel-good-manager, and lecturer. I am extremely thankful to have had such a diverse spectrum of experiences during my time at the Chair of Information Management. I would like to sincerely thank Prof. Dr. Lutz Kolbe as first advisor on my thesis for giving me the opportunity to pursue a research topic that fascinates me and providing the support and encouragement that forms the foundation of the success of the Chair of Information Management.

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Aside from my academic team, it is my pleasure to thank my friends, fellow musicians, and triathlon teammates. You enrich and provide balance to my life, challenge and inspire me, and make my free time so much more enjoyable.

And finally, I would like to express my deep gratitude to my family for their unwavering support and indubitable patience. Georg and Christiane, you are the best role models I could ever imaging and the kindest, most loving, and selfless people I know. Maria, your perseverance inspires me greatly. Elisabeth, I would not be the same person without you and your unique kindness in my life.

Olpe, November 2022 Christine Harnischmacher

Abstract

The mitigation of global climate change poses one of the major challenges of the twenty-first century. Governments all around the world have set ambitious climate- and energy-specific targets that shape the development of the energy and transportation sectors. Increasing the share of renewable energies in the energy mix and substituting conventional vehicles with electric vehicles (EVs) at the same time poses significant challenges for the power grid. The coupling of the energy and transportation sectors offers a promising increase in energy efficiency, as the EVs' batteries can be used as storage for the provision of utility services by supplying power to the grid for stabilization. This is known as the vehicle-to-grid (V2G) application. Thus, suitable V2G applications can contribute to the security of energy supply while at the same time promoting electrified transportation and the integration of renewables. These applications are especially efficient in a commercial context, where the capacities of several batteries can easily be aggregated. Despite the promising benefits for the energy sector, the V2G integration is progressing only slowly, as is the electrification of commercial fleets which is a prerequisite for subsequent Information Systems (IS)-enabled V2G application. In order to do justice to the practice-relevant nature of this research endeavor, the focus is placed on research conducted in a case set in the port of Hamburg, where commercial fleet electrification and the V2G application are piloted.

This thesis investigates the role of IS for the electrification and V2G integration of commercial fleets. Four studies were conducted and are compiled in this dissertation. Study 1 conducts an analysis of the current knowledge base on Green IS, which provides insight into the structure and foci of research conducted to enable sustainability through IS. Studies 2 and 3 provide insight into the cost drivers of V2G applications, the specific costs associated with battery degradation when using EVs for grid stabilization. The results inform a final study that focuses on perpetuating the transformation of commercial transport by examining the influencing factors of fleet electrification processes and deconstructing barriers through IS interventions.

In sum, this dissertation demonstrates the feasibility and provides guidelines for incorporating commercial electrified fleets as an active component of the energy economic value chain. The understanding gained enables viewing fleet electrification and V2G integration as IS-enabled amplification of the energy economic value chain towards ecological sustainability.

The findings presented in this dissertation have implications for researchers concerned with furthering ecological sustainability through Green IS as well as for practitioners seeking to shape the changeover from conventional to electric vehicles in an economically and ecologically beneficial way.

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List of Abbreviations

ACS	Automated Charging Station
AGV	Automated Guided Vehicle
BLD	Battery Life Duration
CO2	Carbon Dioxide
DOD	Depth of Discharge
EDM	Energy Throughput
EV	Electric Vehicle
FCR	Frequency Containment Reserve
FRESH	Flexibilitätsmanagement und Regelenergiebereitstellung von Schwerlastfahrzeugen im Hafen
GHG	Greenhouse Gas
ICT	Information and Communication Technology
IS	Information Systems
IT	Information Technology
RFC	Rainflow Counting
SOC	State of Charge
V2G	Vehicle-to-Grid
VPP	Virtual Power Plant

A. Foundations

The first part of this thesis is divided into two sections.

The following introduction motivates this thesis (A.I). With respect to the current information systems (IS) research, this section introduces important research concepts, gaps, and questions, as well as an overview of the anticipated contributions of this cumulative thesis.

The second section (A.II) introduces Green IS and Energy Informatics as the research background of this work. Furthermore, it provides insight into the importance of IS in the mobility and transportation sector and gives an overview of the research project, which serves as a case study for this thesis.

I. Introduction

This section introduces the research topic and agenda of this thesis. Starting with the research motivation and the relevance of the research endeavor in the first section (I.1), the second section (I.2) highlights the research gaps and questions addressed in this thesis. Subsequently, the thesis' structure is presented (I.3), followed by the positioning and design (I.4), as well as an overview of anticipated contributions (I.5).

I.1 Motivation

The world that we are living in is undoubtedly thriving in numerous aspects. Economies and populations are growing, and people have the ability to become more educated than ever before (de Wit and Altbach 2021). However, these immense opportunities do not come without major challenges (Robinson 2019). While trends such as automation and digitization offer positive chances, one of the most pressing matters that humanity is facing nowadays is global climate change. The depreciation of natural resources and increasing greenhouse gas (GHG) emissions are just two noteworthy developments that have not yet been tackled effectively. These complex challenges concern all of humankind, and thus joint solutions need to be developed and put into practice at a global level (Jordan and Moore 2020; Melville 2010).

One strategy to approach these challenges is climate change mitigation, which aims to prevent the causes of climate change from persisting or arising (Al-Ghussain 2019; Fawzy et al. 2020). As empirical evidence jointly points out the crucial role that increased and anthropogenic GHG emissions play in global warming (Hansen and Stone 2015; Huber and Knutti 2012; Schiermeier 2011), the primary focus of mitigation is on emitting less or no GHGs, for example through burning fewer fossil fuels in the context of energy production or individual and freight transportation. Consequently, a profound paradigm shift in the energy sector of many industrialized countries around the globe has occurred in recent years. Several governments — including Germany's — have committed themselves to establish future energy systems that foster the usage and integration of renewable resources in energy generation, reduce the energy intensity of demand, and lead to more sustainable and effective use of energy (Kitzing et al. 2012; REN21 2020).

The German government, in particular, has formulated ambitious climate- and energy-specific targets that shape the development of the energy system (Bundestag 2021). Energy production was responsible for 30% of GHG emissions in Germany in 2020 and thus the largest source of emissions (Umweltbundesamt 2021). In order to reduce overall GHG emissions by at least 88% compared to 1990 by 2040, a shift towards renewable energies in energy production is inevitable (Klaus et al. 2010). In 2020, renewable energies accounted for 41.1% of total power generation in Germany; however, with a